Chapter 4
Higher Education in Science and Engineering

Contents

Highlights

Characteristics of U.S. Higher Education Institutions

♦ **The defining characteristics of U.S. higher education today that foster access—a broad array of institutional types and sizes, public and private funding, and flexible attendance patterns—were already in place by the early 1950s.** The number of institutions of higher education, however, has doubled since the early 1950s: from approximately 1,870 to 3,700 in 1996. This large and diversified set of institutions provides an undergraduate education to nearly one-third of the U.S. college-age population. This access to higher education is still among the broadest in the world.

♦ **In the past 50 years, enrollment in U.S. higher education has grown from 2.5 million students to more than 14 million.** The four-decade expansion in enrollment in U.S. higher education reached its peak in 1992, when 14.7 million students were enrolled. Enrollment declined and leveled off from 1993 to 1996 and started to rise again in 1997. As the college-age population increases after the year 2000, enrollment in higher education is expected to rise again.

♦ **Although the diverse spectrum of institutions provides relatively high access to higher education in the United States, research-intensive universities produce the majority of engineering degrees and a large proportion of natural and social science degrees at the graduate and undergraduate levels.** The country's 126 research universities awarded more than 42 percent of all science and engineering (S&E) degrees in 1996 at the bachelor's level and 52 percent of all S&E degrees at the master's level.

♦ **Research universities are less prominent in the undergraduate S&E education of underrepresented minority groups than they are in the overall student population.** Black students receive their undergraduate S&E education mainly in comprehensive universities and liberal arts colleges. Historically black colleges and universities (HBCUs) still play a significant role in the undergraduate S&E education of black students.

Undergraduate S&E Students and Degrees in the United States

♦ **The relatively low level of mathematics and science proficiency of U.S. 12th graders is evident among entering first-year college students.** In 1997, 22 percent of first-year students who intended an S&E major reported that they needed remedial work in mathematics. In addition, 10 percent reported that they needed remedial work in the sciences. The need for remedial work in mathematics and science has remained high over the past 20 years, with some differences by field of intended major.

♦ **In the past two decades, the U.S. college-age population declined by more than 21 percent—from 21.6 million in 1980 to 17.0 million in the year 2000.** Trends described in this chapter on decade-long declining enrollment and degrees in several fields of natural science and engineering (NS&E) reflect this demographic situation. The college-age population decline reverses itself in the year 2001, however, and increases to 19.3 million by the year 2010 (a 13-percent increase over the year 2000 figure). This increase in the college-age population portends another wave of expansion in U.S. higher education—and growth in S&E degrees at all levels.

♦ **Echoing this overall demographic decline, the number of students enrolling in undergraduate engineering decreased by 16 percent, from a high point of 441,200 students in 1983 to 356,000 in 1996.** This trend turned around slightly in 1997 and 1998, with a 1.5-percent increase in engineering enrollment. Trends in graduate engineering enrollment differ: graduate enrollment increased from 1979 to 1993 but has declined each year since.

♦ **Since the 1950s, trends in total undergraduate S&E degrees show continuous upward growth, although engineering, mathematics, and computer science fields show declining numbers of degrees in the late 1980s and the 1990s.** The growth in overall S&E degrees occurred in two waves: the first in the 1950s and 1960s and the second in the 1990s. The only fields with an increasing number of earned degrees in the 1990s have been psychology and biological sciences—fields in which women are highly represented. The entry of women into these fields has offset the overall demographic downturn.

International Comparison of First University Degrees in S&E

♦ **In 1997, more than 2.7 million students worldwide earned a first university degree in science or engineering.** Among reporting countries, more than 1 million of the 2.7 million S&E degrees were earned by Asian students within Asian universities. Students across Europe (including Eastern Europe and Russia) earned more than 750,000 first university degrees in science and engineering. Students in the North American region earned 500,000 first university degrees in these fields.

♦ **Some countries emphasize S&E fields in higher education more than others do.** In several large countries—Japan, Russia, and Brazil, for example—more than 60 percent of students earn their first university degrees in S&E fields, and in China, 72 percent do. In contrast, U.S. students study in a wide variety of non-S&E fields; they earn about one-third of their bachelor-level degrees in S&E fields (mainly in the social sciences).

♦ **Countries differ with regard to field emphases within science and engineering.** Engineering represents 46 percent of the earned bachelor's degrees in China, about 30 percent in Sweden and Russia, and about 20 percent in Japan and South Korea. In contrast, students in the United

States earn about 5 percent of bachelor-level degrees in engineering fields. Countries with high concentrations of university degrees in the natural sciences include Ireland (34 percent), France and India (about 20 percent), and the United Kingdom (18 percent). Natural sciences represent almost 12 percent of total U.S. bachelor-level degrees.

- **Among the major industrialized countries in the world, the United States is one of the leading nations in providing broad access to higher education.** In 1997, the ratio of the number of bachelor-level degrees to the 24-year-old population was 32 per hundred in the United States, 35 in the United Kingdom, 28 in Japan, and 24 in Germany. The ratios for Italy and France were 13 per hundred in that same year.

- **The United States ranks below many major industrialized and emerging countries, however, in the proportion of its college-age population with a natural science or engineering degree.**[1] In 1997, the ratio of the number of NS&E degrees to the 24-year-old population in the United States was about 5 per hundred. This U.S. ratio has remained relatively constant—between 4 and 5—over the past several decades. In contrast, the ratio of NS&E degrees to the college-age cohort has been rising in other countries. South Korea and Taiwan dramatically increased their ratio of NS&E degrees to 24-year-olds: from 2 per hundred in 1975 to almost 7 per hundred in Taiwan in 1997 and almost 9 per hundred in South Korea. Among European countries, by 1997 this ratio had increased to 9 per hundred in the United Kingdom and 8 per hundred in Germany.

Graduate S&E Students and Degrees in the United States

- **One indicator of national innovation capacity and potential international competitiveness is the size and growth of graduate programs in science and engineering.** The long-term trend of increasing enrollment in U.S. graduate programs in S&E persisted for more than four decades, from the late 1940s to the early 1990s, followed by four years of declining enrollment since 1993.

- **Increases in S&E degrees at the master's level persisted for more than four decades, with accelerated growth in the first half of the 1990s and a leveling off in 1996.** Master's degrees in S&E fields expanded from the modest number of 13,500 in 1954 to more than 95,000 in 1996.

- **Doctoral S&E degree production in U.S. universities shows two waves of strong growth in the last half of the 20th century.** The first upsurge of total doctoral S&E degrees in the late 1950s and 1960s reflected the Cold War and the space race and was followed by a long, slow decline in NS&E fields in the 1970s and in the social sciences in the 1980s. In the 1980s, the second wave of growth occurred in NS&E fields with large annual increases in academic research and development (R&D) budgets. From 1986 to 1992, increasing numbers of foreign students entered these expanded graduate programs in NS&E fields.

[1] Natural sciences and engineering include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences; mathematics and computer science; and all fields of engineering.

International Comparison of Doctoral Degrees in S&E

- **The United States has the highest number of doctoral degrees earned in S&E fields.** In 1997, U.S. universities awarded about 26,800 S&E doctoral degrees—more than twice the number of S&E degrees awarded in any of the other major industrial countries. However, the combined doctoral S&E degrees of the three largest European countries (Germany, France, and the United Kingdom) recently reached 27,800, surpassing the number of such degrees earned within the United States.

- **Asian graduate education reforms are strengthening and expanding doctoral programs; consequently, some Asian countries are becoming somewhat less dependent on U.S. universities for advanced training in S&E.** In 1997, the number of S&E doctoral degrees earned within major Asian countries (China, India, Japan, South Korea, and Taiwan) exceeded 18,500—representing a 12-percent average annual increase from 1993 to 1997. In contrast, such degrees earned by Asian students from these five countries within U.S. universities peaked at 6,900 in 1996 (representing less than a 5-percent average annual growth rate from 1993 to 1996) and declined in 1997.

- **China has invested heavily in graduate education.** While the number of S&E doctoral degrees earned by Chinese students within U.S. universities showed a decade-long increase until 1996, the number of such degrees earned within Chinese universities continued to increase, and at a faster rate. By 1997, Chinese students earned more than twice as many S&E doctorates within Chinese universities as within U.S. universities.

Diversity Patterns in S&E Enrollment and Degrees in the United States

- **The trend of increasing enrollment in undergraduate programs by underrepresented minorities (including black, Hispanic, and American Indian/Alaskan Native students) has persisted for more than a decade and continued in the 1990s.** Black enrollment increased 3 percent annually from 1990 to 1996, reaching 1.4 million in 1996. Black males have had more modest gains than black females. In the same period, Hispanic enrollment in higher education increased at an even faster rate (7.7 percent annually). The strongest growth, however, has been among Asians/Pacific Islanders (8 percent annually)—minority groups that are not underrepresented in S&E fields.

- **Despite the overall trend of decreasing enrollment in undergraduate engineering in the past two decades, underrepresented minority groups increased their enrollment in such programs during this same time period.** The number of minority students enrolled in engineering increased from 28,700 in 1979 to 56,900 in 1998—an average annual increase of 3.7 percent. By 1998, underrepresented minorities represented 15.5 percent of engineering enrollment at the undergraduate level (up from 7.8 in 1979).

- ♦ **Compared with other groups, fewer underrepresented minority students complete a bachelor's degree within five years after beginning an S&E major.** In a longitudinal study, 47 percent of whites and Asians/Pacific Islanders completed an S&E degree within 5 years, compared with 25 percent of underrepresented minority groups. However, a larger percentage of underrepresented minority groups persisted in studying for an S&E bachelor's degree beyond five years. (Taking longer may reflect working part-time.) In addition, underrepresented minority groups switched to non-S&E majors more often than other groups. Attrition rates (dropping out of college) are similar across all groups—about 22 percent.
- ♦ **Students from underrepresented minority groups earn a higher proportion of degrees at the associate's level than in four-year or graduate programs.** In 1996, these students earned about 23 percent of the mathematics and computer science degrees at the associate's level, a far higher percentage than for such degrees earned at the bachelor's or advanced levels of higher education. At advanced levels, the proportion of degrees earned by underrepresented minorities drops off in fields of NS&E.
- ♦ **The United States is among the leading countries in the world in the proportion of first university S&E degrees earned by women.** By 1996, women earned 60 percent of the social and behavioral science degrees, 47 percent of the natural science degrees, 46 percent of the degrees in the mathematical sciences, 28 percent of the degrees in computer sciences, and 18 percent of the degrees in engineering. Women in the United Kingdom earn a similarly high proportion of S&E degrees. In contrast, in Japan women earn a smaller proportion of such degrees: 25 percent of natural science degrees, 23 percent of mathematics and computer science degrees, and 8 percent of engineering degrees.
- ♦ **Although low participation rates for blacks and Hispanics changed little throughout the 1980s, they have improved somewhat in the 1990s.** The ratio of college degrees earned by black students to their college-age population increased from 11 per hundred in 1980 to 18 per hundred in 1996; the ratio for Hispanic groups increased from 10 per hundred in 1980 to 14 per hundred in 1996. The ratio of NS&E degrees earned by black students to their college-age populations increased from 1 per hundred in 1980 to 2 per hundred in 1996, and the ratio for Hispanics rose from slightly under 2 per hundred in 1980 to slightly more than 2 per hundred in 1996. Even with these modest increases in the 1990s, however, participation rates of underrepresented minorities are approximately one-half the overall national rates.
- ♦ **For the period 1983–92, the strong growth in enrollment in U.S. graduate programs in S&E depended on the entry of foreign students, particularly in programs of natural science and engineering (NS&E).** In 1992, at the peak of their enrollment in U.S. graduate programs, foreign students represented one-third of the students in engineering, mathematics, and computer sciences. From 1993 to 1996, foreign graduate student enrollment declined at an average annual rate of 3 percent, with a slight upturn in 1997. The slight drop in doctoral degrees in NS&E fields in 1997 is mainly attributable to the decline in the number of foreign doctoral recipients in that year.
- ♦ **Among underrepresented minority groups, males are not as prevalent in fields of NS&E; women in these groups have a higher proportion of graduate enrollment compared with the overall average.** For example, women are one-third of the black graduate students in engineering and more than one-half of the black graduate students in fields of natural sciences. Black males are extremely underrepresented in U.S. higher education in general and in S&E fields in particular.
- ♦ **Gender equity in S&E degrees at the master's level has improved continually during the past four decades.** By 1996, women earned 58 percent of the master's degrees in the social and behavioral sciences and 49 percent in the biological sciences. However, they earned only 27 percent of computer science degrees and 17 percent of those in engineering. Degrees earned by males have declined in engineering for the past two years, mainly because of declining engineering enrollment by foreign students.
- ♦ **Each year from 1986 to 1996, an increasing number of foreign students earned S&E doctoral degrees from U.S. universities.** The number of such degrees earned by foreign students increased far faster (8 percent annually) than those earned by U.S. citizens (2 percent annually). This decade-long trend of increasing numbers of S&E doctoral degrees earned by foreign students halted in 1997. In that year, the number of degrees earned by foreign doctoral students dropped by 15 percent.
- ♦ **Like the United States, the United Kingdom, Japan, and France have a large percentage of foreign students in their doctoral S&E programs.** In 1997, foreign students earned 45 percent of the doctoral engineering degrees awarded within U.K. universities, 43 percent of the doctoral engineering degrees within Japanese universities, and 49 percent of the doctoral degrees within U.S. universities. In that same year, foreign students earned more than 21 percent of the doctoral degrees in the natural sciences in France, 29 percent in the United Kingdom, and 36 percent in the United States.
- ♦ **About 53 percent of the foreign students who earned S&E doctorates from U.S. universities in 1992 and 1993 were working in the United States in 1997.** The stay rates are higher for scientists and engineers from developing countries such as China (92 percent) and India (83 percent). In contrast, stay rates are lower for those from emerging economies such as Taiwan (36 percent) and Korea (9 percent) that can absorb highly qualified, skilled scientists and engineers.

Introduction

Chapter Overview

Many recommendations for strengthening higher education in science and engineering that were made a half-century ago in Science and Public Policy[2] are still being implemented or are still of national concern (Steelman 1947). These recommendations of the President's Scientific Research Board—referred to herein as the Steelman report—included expanding institutions of higher education, training scientists and engineers in all fields of knowledge, and providing U.S. leadership in disseminating scientific knowledge. This chapter suggests that several of these recommendations have been accomplished, as the trends regarding expansion of and greater access to higher education and the leadership role of U.S. universities in training scientists and engineers from around the world demonstrate. This chapter also addresses other recommendations that are still topics of concern, such as improving the teaching and research experience of undergraduates, educating adequate numbers of students willing and able to pursue advanced S&E programs, and creating the "right" number of S&E doctorates to meet the needs of the workplace. In addition, this chapter presents indicators on current concerns that are different from those of the past—especially the participation of women and minorities in S&E, the dependence on foreign students in U.S. graduate S&E programs, and the stay rates and return patterns of foreign doctoral recipients.

Chapter Organization

This chapter begins with a review of the growth of U.S. higher education from the early 1950s; this review presents the characteristics of the diverse set of institutions that fostered this growth. The chapter notes the prominence of research universities in the expansion of S&E degrees, as well as the continuing importance of comprehensive and liberal arts colleges. The review highlights increased access to higher education provided by community colleges.

The main body of the chapter presents trends in enrollment and degrees in broad fields of S&E at various levels—associate's, bachelor's, master's, and doctorate. The characteristics of U.S. freshmen show their intentions to major in S&E as well as some lack of readiness for college-level work. Following the review of bachelor-level trends, international data are presented to compare participation rates across several world regions. In addition, international comparisons are made at the doctoral level, and information is presented on the worldwide movement toward expansion and reform of graduate S&E education. Further international comparisons are made with regard to the participation of women in S&E fields at the bachelor's and doctoral levels and the proportion of doctoral degrees earned by foreign students.

[2]See chapter 1.

The final sections of the chapter address patterns of diversity in U.S. higher education. The increasing representation of women and minorities in S&E degrees is shown over time and by field. Long-term trends of increasing foreign student enrollment and degrees, as well as recent downturns in these trends, are discussed.

Other chapters of this volume cover related topics in S&E education. Chapter 3, "Science and Engineering Workforce," discusses the entry of S&E graduates at various levels into the U.S. labor force in S&E occupations and the contribution of foreign doctoral recipients who remain in the United States for teaching and research. Chapter 6, "Academic Research and Development," includes indicators of graduate student financing, faculty composition, and the link between R&D funding and graduate enrollment; the bibliometric section of that chapter also provides initial indicators of the growing percentage of the world's scientific literature from countries expanding their graduate education in S&E. Chapter 7, "Industry, Technology, and the Global Marketplace," provides initial indicators of competitiveness—high technology trade and patenting—of countries that have expanded their doctoral S&E training and are building their science infrastructure. Chapter 9, "Significance of Information Technologies," includes the impact of technology on higher education.

Characteristics of U.S. Higher Education Institutions

The defining characteristics of U.S. higher education that foster access—a broad array of institutional types and sizes, public and private funding, and flexible attendance patterns—were already in place in the early 1950s. In 1953, more than 1,870 institutions—including universities; liberal arts colleges; teachers' colleges; and technological, theological, and other professional schools—were providing higher education. These diverse institutions included public and private colleges and universities and provided for part-time attendance. One-fifth of the undergraduate students were enrolled part-time (U.S. HEW 1956). Students were concentrated in universities and liberal arts colleges; only 13 percent were enrolled in junior colleges. (See text table 4-1.)

Expansion of Institutions

These underlying characteristics of U.S. higher education have persisted during the past 50 years, with expansion occurring through the establishment of many new institutions and the increasing size of universities. In 1953, the largest universities enrolled approximately 10,000 students. By 1996, the largest U.S. universities enrolled between 25,000 and 50,000 students (HEP 1996). Enrollment has surged within research and comprehensive universities. A number of teachers' colleges expanded their offerings and became comprehensive and doctoral institutions. While the number of universities has doubled since the 1950s, the number of two-

Text table 4-1.
U.S. institutions of higher education, by type and enrollment level: 1953

Type	Number	Enrollment
Total	1,871	2,534,709
Universities	131	1,154,719
Liberal arts colleges	713	636,479
Teachers' colleges	200	208,573
Technological schools	53	114,077
Theological schools	115	31,205
Other professional	138	61,986
Junior colleges	498	339,867

SOURCE: U.S. Department of Health, Education, and Welfare (HEW), *Statistics of Higher Education: Faculty, Students, and Degrees 1953–54* (Washington, DC: U.S. Government Printing Office, 1956).

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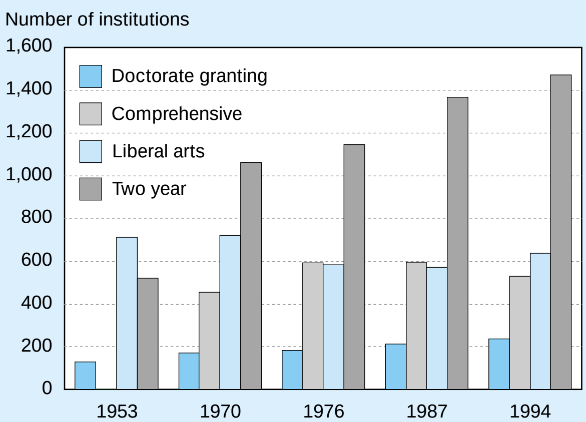
year institutions has tripled—from 521 in 1953 to 1,569 in 1996 (HEP 1996). (See figure 4-1.)

Alongside the growth of large institutions in U.S. higher education, liberal arts institutions have remained relatively small. In 1953, liberal arts colleges enrolled approximately 0.6 million students in 713 institutions. By 1996, 1.1 million students were enrolled in approximately 637 such undergraduate colleges (reflecting an average enrollment of less than 2,000 students).

Today's large and diversified set of institutions provides an education at the bachelor's level to approximately one-third of the U.S. college-age population. (See "Undergraduate S&E Students and Degrees in the United States.") Access to U.S. higher education is still among the highest in the world, although other countries are also broadening access and expanding graduate programs, particularly in S&E. (See "International Comparison of First University Degrees in S&E," "International Comparison of Doctoral Degrees in S&E," and sidebar, "Graduate Reforms in Europe, Asia, and Latin America.")

Figure 4-1.
Number of institutions of higher education, by type: 1953–94



NOTES: Universities were not categorized as "comprehensive" in 1953; 1953 data on institutional categories are not strictly comparable with the later data, which are based on the Carnegie Classification of Education. A number of comprehensive universities became doctorate-granting institutions between 1987 and 1994.

See appendix table 4-1. *Science & Engineering Indicators – 2000*

In the United States, there were 3,660 (1,580 public and 2,080 private) two- and four-year institutions of higher education in 1996 (HEP 1996). These institutions enrolled 14.5 million students at all degree levels in that year and awarded 2.2 million degrees, one-quarter of which were in S&E. (See figure 4-2.)

More than 5 million of the 14.5 million students are enrolled in community colleges. These institutions increase the openness of U.S. higher education; through considerable remedial coursework, they provide a second chance for students who were not well served by, or well motivated during, their high school education. They also foster movement into four-year institutions through arrangements that allow students to transfer their credits from community colleges to four-year colleges and universities.

To better describe this diverse set of institutions serving a variety of needs, the Carnegie Foundation for the Advancement of Teaching has clustered institutions with similar programs and purposes. (See sidebar, "Carnegie Classification of Institutions.")

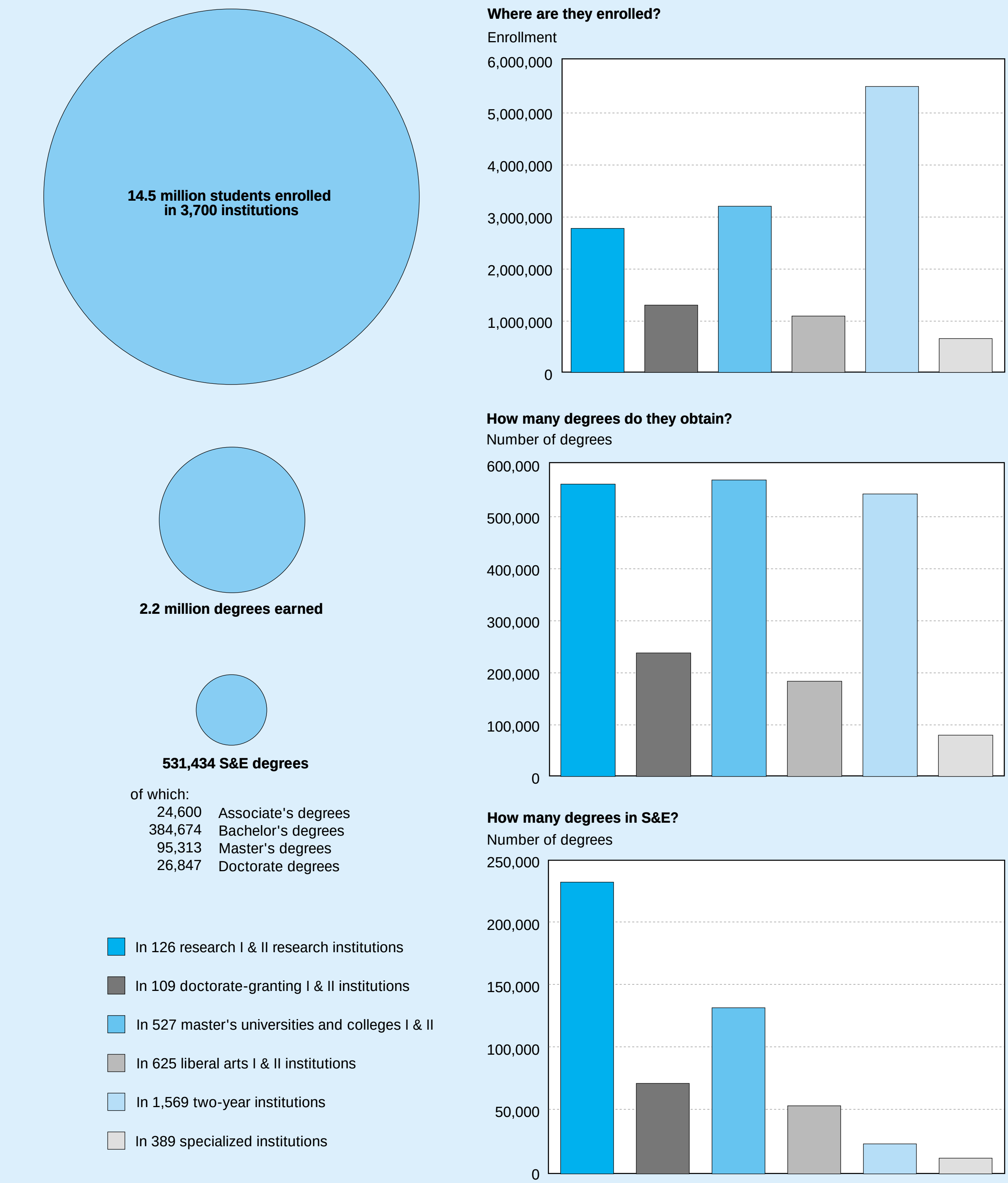
Long-Term Trends in Enrollment in U.S. Higher Education

The four-decade expansion in enrollment in U.S. higher education reached its peak in 1992, when more than 14.6 million students were enrolled, and then leveled off. This expansion first accelerated in the late 1940s and early 1950s; by 1950, higher education enrollment had surged to 2.7 million students (up from 1.2 million in 1944) as a result of the post-World War II influx of veterans supported under the GI Bill (U.S. HEW 1956).[3] After the influx of returning veterans subsided, the number of (nonveteran) college students grew steadily for several decades, from the 1960s to the early 1990s, reaching a peak of more than 14.6 million students in 1992. Following more than four decades of such growth in higher education, graduate enrollment began a slight decline in 1993; undergraduate enrollment began declining in 1995. (See "Undergraduate S&E Students and Degrees in the United States" and "Graduate S&E Students and Degrees in the United States.")

From 1967 to 1992, enrollment in U.S. institutions of higher education expanded an average of 3 percent annually, but growth rates differed greatly by type of institution. For example, two-year colleges grew at twice this rate and accounted

[3]In that year, 1950, veterans represented 35 percent of the students in higher education.

Figure 4-2.
U.S. higher education in 1996: students, institutions, and degrees at all levels



NOTE: The 355 institutions classified as "other" are not included.

See appendix tables 4-2, 4-3, and 4-4.

Science & Engineering Indicators – 2000

Carnegie Classification of Institutions

Carnegie has classified higher education institutions into 10 categories based on the size of their baccalaureate and graduate degree programs, the amount of research funding they receive, and—for baccalaureate colleges—their selectivity.* Following is a brief description of these categories.

- **Research universities I.** These institutions offer a full range of baccalaureate programs, are committed to graduate education through the doctorate level, and give high priority to research. They award 50 or more doctoral degrees each year and annually receive $40 million or more in Federal research support.
- **Research universities II.** These institutions are the same as research I universities, except that they receive between $15.5 million and $40 million annually in Federal research support.
- **Doctorate-granting I.** In addition to offering a full range of baccalaureate programs, the mission of these institutions includes a commitment to graduate education through the doctoral degree. They award 40 or more doctoral degrees annually in at least five academic disciplines.
- **Doctorate-granting II.** These institutions are the same as doctorate-granting I institutions, except that they award 20 or more doctoral degrees annually in at least one discipline or 10 or more doctoral degrees in three disciplines.
- **Master's (comprehensive) universities and colleges I.** These institutions offer baccalaureate programs and, with few exceptions, graduate education through the master's degree. More than half of their baccalaureate degrees are awarded in two or more occupational or professional disciplines, such as engineering or business administration. All of the institutions in this group enroll at least 2,500 students.
- **Master's (comprehensive) universities and colleges II.** These institutions are the same as master's universities and colleges I, except that all of the institutions in this group enroll between 1,500 and 2,500 students.
- **Baccalaureate (liberal arts) colleges I.** These highly selective institutions are primarily undergraduate colleges. They award more than 40 percent of their baccalaureate degrees in liberal arts and science fields.
- **Baccalaureate (liberal arts) colleges II.** These institutions are primarily undergraduate colleges that award less than 40 percent of their degrees in liberal arts and science fields. They are less restrictive in admissions than baccalaureate colleges I.
- **Associate of arts colleges.** These institutions offer certificate or degree programs through the associate degree level and, with few exceptions, offer no baccalaureate degrees.
- **Professional schools and other specialized institutions.** These institutions offer degrees ranging from the bachelor's to the doctorate. At least half of the degrees awarded by these institutions are in a single specialized field. These institutions include theological seminaries, bible colleges, and other institutions offering degrees in religion; medical schools and centers; other separate health profession schools; law schools; engineering and technology schools; business and management schools; schools of art, music, and design; teachers' colleges; and corporate-sponsored institutions.

*The Carnegie classification is not an assessment guide, nor are the distinctions between classification sublevels (for example, research I and research II) based on institutions' educational quality. Baccalaureate college I institutions exercise more selectivity regarding students than do baccalaureate colleges II, but in general the Carnegie categories are a typology, not a rank ordering.

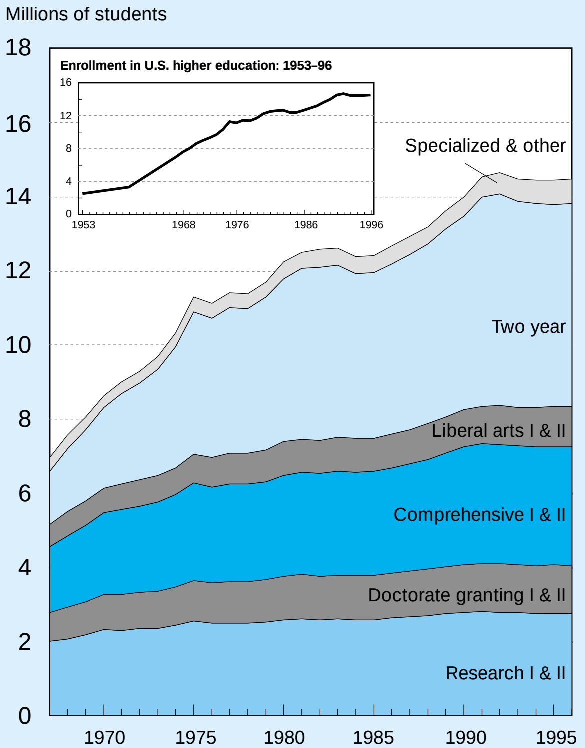
for the largest share of the growth—from 0.2 million students in 1950 to 5.5 million students in 1996. (See appendix table 4-2 and U.S. HEW 1956.) In 1950, two-year college enrollment was 9 percent of overall higher education enrollment. By 1996, enrollment in two-year colleges was 38 percent of higher education's total enrollment. In contrast, student enrollment in research I universities grew more modestly, from 1.5 million students in 1967 to 2.1 million in 1991 (with slight declines since then).[4] Research universities enroll only 19 percent of the students in higher education, but they play the largest role in S&E degree production. (See figure 4-3 and appendix table 4-2.)

[4]Research institutions, however, account for significant numbers of S&E degrees; two-year colleges do not. (See figure 4-2 and "S&E Degree Production by Type of Institution.")

S&E Degree Production by Type of Institution

A diverse spectrum of institutions provides for relatively high access to higher education in the United States, but the research-intensive universities produce the majority of engineering degrees and a large proportion of natural and social science degrees at both the graduate and undergraduate levels. (See figures 4-4 and 4-5.) In 1996, the country's 126 research universities awarded more than 42 percent of all S&E degrees at the bachelor's level and 52 percent of all S&E degrees at the master's level. (See appendix table 4-3.) In addi-

Figure 4-3.
Enrollment in U.S. higher education, by institution type: 1967–96



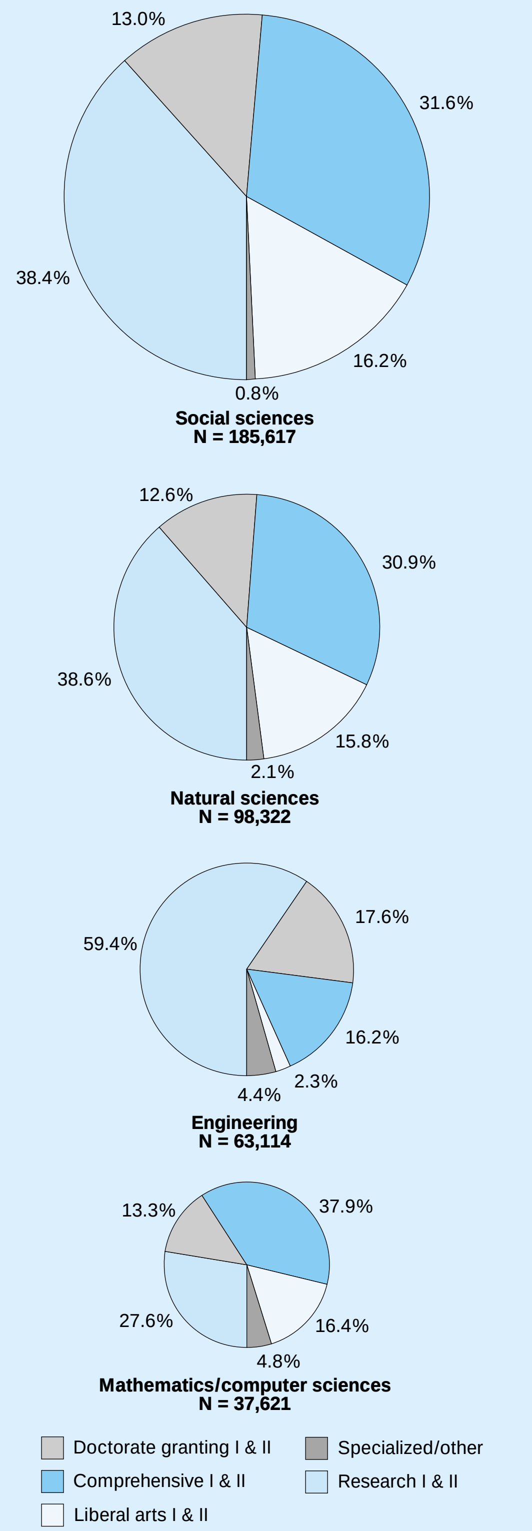
See text table 4-1 and appendix table 4-2.

Science & Engineering Indicators – 2000

tion, comprehensive and liberal arts I institutions produce significant numbers of bachelor's and master's degrees in science and engineering. (See appendix table 4-3.)

The proportion of S&E degrees earned by institution type in U.S. higher education, however, is not homogeneous for all groups. In contrast to the overall student population, S&E degrees earned by underrepresented minorities are less concentrated in research universities; minority-serving institutions still play a significant role in minorities' S&E education. These students earn a far smaller percentage of their bachelor-level degrees in the natural and social sciences at research universities, compared with their engineering degrees and with the percentage of such degrees earned by the overall student population. Over the past 20 years, underrepresented minority students have earned higher percentages of their degrees within research universities in social science and engineering fields, but not in natural science fields. By 1996, underrepresented minority students earned 44 percent of their bachelor-level engineering degrees at research universities, up from 32 percent in 1977. (See appendix table 4-5.) However, the relatively small percentages of degrees earned by underrepresented minority students within research universities have remained stable over the past 20 years. (See appendix table 4-5 and text table 4-2.)

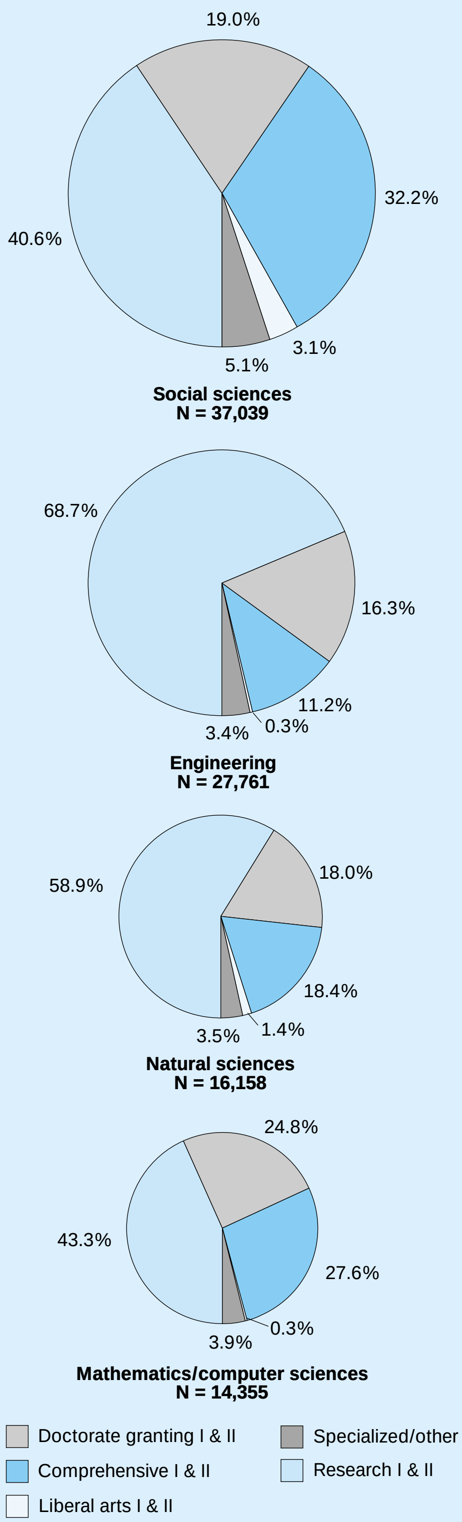
Figure 4-4.
Bachelor's degrees awarded in S&E, by institution type: 1996



NOTES: Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix table 4-3. *Science & Engineering Indicators – 2000*

Figure 4-5.
Master's degrees awarded in S&E, by institution type: 1996



NOTES: Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix table 4-3. *Science & Engineering Indicators – 2000*

Text table 4-2.
Percentage of S&E bachelor's degrees earned by underrepresented minorities within research universities: 1996

Field	Total student population	Underrepresented minorities
Total S&E	42	31
Natural sciences	39	25
Social sciences	38	32
Engineering	60	44

See appendix tables 4-3 and 4-5.

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Black students have traditionally earned a large percentage of their S&E degrees within historically black colleges and universities (HBCUs)—mainly comprehensive universities and liberal arts colleges. HBCUs, originally established during the period of legalized segregation for the purpose of educating blacks, continue to produce large percentages of the S&E bachelor-level degrees earned by black students. These comprehensive universities and liberal arts colleges produce 30 percent of their engineering degrees, 44 percent of their natural science degrees, and 25 percent of their social science degrees. These percentages have remained relatively stable for the past 20 years. (See appendix table 4-5 and NSF 1999c.)

The associate of arts colleges, which enroll more than 5 million students, account for only a small percentage of S&E degrees. These two-year colleges, however, provide continuing education and flexibility in the U.S. higher education system, allowing students to complete required work-related courses or obtain coursework credits for transfer to a four-year college or university. An analysis of undergraduate careers in engineering in 1995 showed that one out of six students who received a bachelor's degree in engineering, engineering technology, or architecture started in a community college (USDE 1998).

Baccalaureate Origins of Ph.D.s

The 126 research universities provide the baccalaureate education of the majority (56 percent) of S&E doctoral recipients. However, liberal arts colleges and comprehensive universities also contribute a significant proportion of bachelor-level degrees among students who later complete doctoral S&E degrees. Each of these institution types provides 15 percent of the baccalaureate education of doctoral recipients; within individual fields they are even more prominent. For example, 23 percent of the students earning doctorates in chemistry received their undergraduate education within a liberal arts college, and an additional 23 percent received their undergraduate education within a comprehensive university. (See appendix table 4-6.)

Demographics and U.S. Higher Education

The U.S. college-age population has declined by more than 21 percent in the past two decades, from 21.6 million in 1980 to 17.0 million in the year 2000. This demographic decline is reflected in the trends presented in this chapter, including the declining number of bachelor's degrees in several fields of NS&E beginning in the late 1980s. (See figure 4-6.) This 20-year population decline of the college-age cohort reverses itself in the year 2000, and increases to 19.3 million by the year 2010. (See appendix table 4-7.) The increase in the college-age population by more than 13 percent in the first decade of the 21st century portends another wave of expansion in U.S. higher education—and growth in S&E degrees at all levels.

Undergraduate S&E Students and Degrees in the United States

Characteristics of American College Freshmen

Intentions to Major in S&E

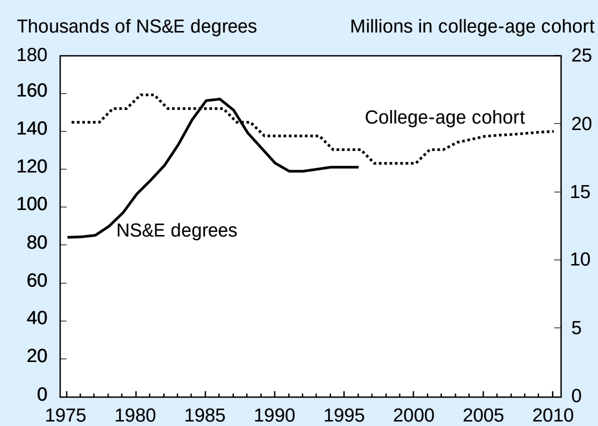
The issue of whether women and minorities are attracted to S&E majors is of national interest because they now make up the majority of the labor force. Their successful completion of S&E degrees will determine the adequacy of entrants into the S&E workforce in the United States. This section reports on two longitudinal surveys of student intentions to major in S&E, by race, ethnicity, and sex. (See "Bachelor's Degrees," "Trends in Earned S&E Degrees.") The Higher Education Research Institute's (HERI) Freshman Norms Survey annually surveys a nationally representative sample of first-year students in four-year colleges and universities about their intention to major in any S&E field (HERI 1998). The National Education Longitudinal Study of 1988 (NELS:88 unpublished tabulations) tracked a large, nationally representative sample of eighth graders and identified in a follow-up survey those who were enrolled in undergraduate S&E programs (NCES 1998b).

The Freshman Norms data show that, by 1998, 47 percent of the first-year college students reporting intentions to major in S&E were women; 53 percent were men (HERI 1998). These data also show increasing racial diversity among students choosing an S&E major. By 1998, underrepresented minority groups represented 19 percent of those intending an S&E major,[5] up from 8 percent in 1971. The trend is toward an increased percentage of black and Hispanic freshmen intending a natural science or engineering major. (See appendix table 4-9.) For example, from 1986 to 1998, the proportion of underrepresented minorities intending to major in the biological sciences rose from 10 percent of first-year college students to 18 percent.[6] (See appendix table 4-9.)

NELS:88 corroborated the findings of the Freshman Norms Survey and showed little difference between racial and ethnic groups with regard to choosing an S&E major. NELS:88 followed students from eighth grade through high school, college, and entry into the labor force. Students who reported being enrolled in an S&E program (generally as sophomores in college) were examined to identify differences by race and sex. Between 9 and 10 percent of all racial/ethnic groups of this cohort were enrolled in S&E programs in 1994. In contrast, the study found a significant difference in the percentage of males and females enrolled in S&E programs: 12 percent of males were enrolled in such programs, whereas only 7 percent of females were enrolled in S&E fields. The gap between males and females is particularly pronounced among (or attributable mainly to) the gaps among white and Asian/Pacific Islander students; among black and Hispanic students, women are essentially on par with men. (See figure 4-7.)

Of the relatively small percentage of students who enroll as S&E majors, less than one-half complete an S&E degree within 5 years. (See "Diversity Patterns in S&E Enrollment and Degrees in the United States.") Although there may be many reasons for this, the disparity between the percentage of students who aspire to study S&E fields and the percentage who complete an undergraduate S&E degree reflects, in part, the lack of readiness of U.S. students for college-level S&E coursework.

Figure 4-6.
Trends in U.S. college-age cohort and bachelor's degrees in selected NS&E fields: 1975–2010



NOTES: NS&E = natural science and engineering. College-age cohort = the 20–24-year-old population. Selected natural sciences include physical, earth, atmospheric, and oceanographic sciences, mathematics, and computer sciences.

See appendix tables 4-7 and 4-17, and National Science Foundation, Science Resources Studies Division, *Science and Engineering Degrees: 1966–96,* NSF 99-330, Author, Susan T. Hill (Arlington, VA, 1999).

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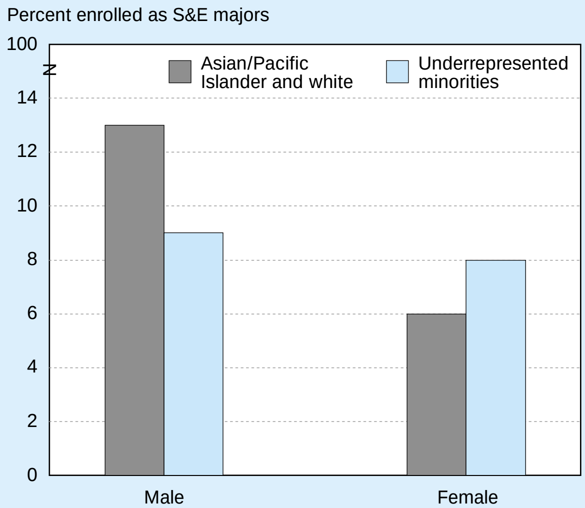
[5]In 1996, white students constituted 67 percent of the 18-year-old population in the United States; underrepresented minority groups constituted 29 percent (U.S. Department of Commerce, Bureau of the Census 1998).

[6]Underrepresented minority students are not uniformly distributed across all institutions, however. They are more concentrated in minority-serving institutions (comprehensive universities and liberal arts colleges) and HBCUs. (See "S&E Degree Production by Type of Institution.")

Figure 4-7.
Enrollment in college as S&E majors, by race/ethnicity and sex



NOTE: 1988 eighth graders who later enrolled in college as S&E majors.

SOURCE: National Center for Education Statistics (NCES), National Education Longitudinal Study (NELS:88), unpublished tabulations.

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Quality of High School Graduates

Are U.S. freshmen ready for college-level coursework? Data from national longitudinal studies (HERI 1998; NELS:88 unpublished tabulations) and the 1994 High School Transcript Study (NCES 1997) provide some indicators of readiness: the increasing number of mathematics and science courses taken, the relatively low level of 12th-grade proficiency in science and mathematics, and the continuing need for remedial work in college.

Trend data from 1971 to 1998 on the number of high school mathematics and science courses that students have taken show that an increasing percentage of entering first-year college students have taken four years of high school mathematics and two to three years of science coursework (HERI 1998). These percentage increases have occurred across all racial groups, though they are somewhat lower among some minority groups. In 1998, between 64 and 75 percent of different subpopulations of entering first-year college students reported that they had completed four years of high school mathematics—a considerable increase from the figures reported in the previous decade. In 1984, between 37 and 65 percent of entering first-year college students reported having four years of high school math. In addition, first-year college students reported an increasing amount of high school coursework in the biological sciences. (See appendix table 4-10.) This increase in mathematics and science courses is corroborated in the 1994 High School Transcript Study, which showed that, from 1982 to 1994, rising percentages of male and female high school graduates had taken various mathematics and science courses. (See text table 4-3.)

Despite the additional mathematics and science coursetaking in high school, a relatively small percentage of 12th graders demonstrate a high level of proficiency in mathematics and science.[7] NELS:88 tracked a representative

[7]The Third International Mathematics and Science Study shows similar findings. U.S. 12th graders scored below the international average and among the lowest of the 21 participating nations in both mathematics and science general knowledge.

Text table 4-3.
Percentage of high school graduates who report having taken mathematics and science courses, by sex: various years

Course	Total				Male				Female			
	1982	1987	1990	1994	1982	1987	1990	1994	1982	1987	1990	1994
Mathematics												
Algebra I	53.9	64.0	64.2	66.4	52.2	62.3	61.7	64.7	55.4	65.7	66.5	68.1
Geometry	45.5	59.7	63.4	70.4	45.0	58.8	62.4	68.3	45.9	60.4	64.4	72.4
Algebra II	32.2	48.1	51.7	58.6	32.4	47.3	50.0	55.4	32.0	48.9	53.3	61.6
Trigonometry	12.1	18.6	18.2	17.2	13.2	19.5	18.1	16.6	11.1	17.6	18.2	17.8
Analysis/precalculus	5.9	12.6	13.4	17.3	6.2	13.5	14.0	16.3	5.6	11.6	12.8	18.2
Calculus	4.6	6.0	6.5	9.2	5.1	7.4	7.5	9.4	4.1	4.6	5.6	9.1
Science												
Biology	76.4	87.8	91.3	93.5	74.2	86.3	90.0	92.3	78.4	89.4	92.5	94.7
Chemistry	30.9	43.7	49.0	56.0	31.9	44.3	47.9	63.2	30.0	43.2	50.0	58.7
Physics	14.2	19.2	21.5	24.4	18.8	24.0	25.4	26.9	10.0	14.6	18.0	22.0
Biology and chemistry	28.1	42.1	47.6	53.8	28.2	42.2	46.4	50.9	28.0	42.0	48.8	56.6
Biology, chemistry, and physics	10.6	16.4	18.8	21.3	13.4	20.1	21.8	23.1	7.9	12.8	16.1	19.6

SOURCE: National Center for Education Statistics (NCES), *The Condition of Education 1997* (Washington DC: 1997). (Data are based on the 1994 High School Transcript Study Tabulations.)

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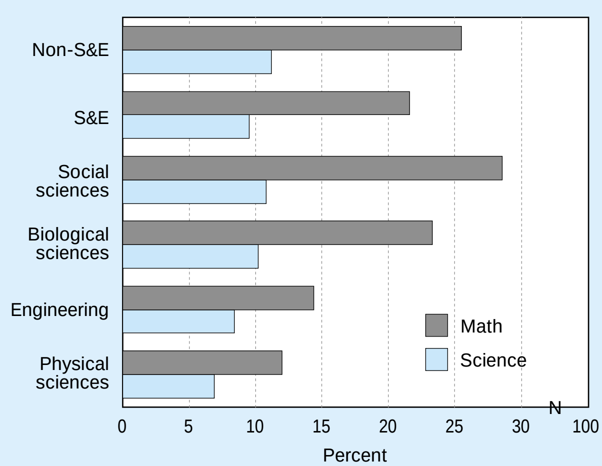
sample of 25,000 students from eighth grade through high school, college, and entry into the labor force. This study included assessment of students' high school course-taking behavior and their mathematics and science proficiency. Analysis of the NELS data shows that in 1992 only about 37 percent of white and Asian/Pacific Islander students reached a high level of proficiency (level 4 or 5) in mathematics; an even smaller percentage of underrepresented minority students achieved this high proficiency (14 percent). In the sciences, only 25 percent of white and Asian/Pacific Islander students reached a high level (level 3) of proficiency in this exam, and even lower percentages of underrepresented minority students (8 percent) reached this level. (See appendix table 4-11.) This low level of science proficiency is also reflected in science literacy data collected with the National Science Foundation's (NSF) survey of public attitudes toward and understanding of science and technology (S&T) (see chapter 8).

Low mathematics and science proficiency is also evident among entering first-year college students. In 1997, 22 percent of first-year college students who intended an S&E major reported that they needed remedial work in mathematics; 10 percent reported they needed remedial work in the sciences. The percentages of students who need remedial work in mathematics and science have remained high over the past 20 years, with some differences by field of intended major. (See appendix table 4-12.) Students intending to major in the physical sciences and engineering report less need for remedial work. In contrast, students intending to major in the social and biological sciences, as well as in non-S&E fields, report more need for remedial work. (See figure 4-8 and appendix table 4-12.)

Figure 4-8.
Freshmen reporting need for remedial work in science or math, by intended major: 1997



See appendix table 4-12. *Science & Engineering Indicators – 2000*

Readiness for College-Level Mathematics

The American Mathematical Society's (AMS) surveys of mathematics courses (five-year incremental studies from 1970 to 1995) show an increasing percentage of remedial mathematics courses at two- and four-year colleges and a decreasing percentage of advanced-level course work at four-year institutions (NSB 1998). In the past decade, fewer students majored in mathematics (see "Bachelor's Degrees"), and universities decreased advanced-level coursework in mathematics. The forthcoming AMS survey of mathematics courses in the year 2000 should be monitored to see whether enrollment in remedial mathematics in four-year institutions continues to remain around 15 percent, or whether it decreases. (See text table 4-4.)

Engineering Enrollment

In contrast to intentions to major in S&E provided above, the annual fall survey of the Engineering Workforce Commission (EWC) obtains data on actual enrollment in graduate and undergraduate programs. Engineering programs generally require students to declare their major as first-year students, allowing enrollment to be used as an early indicator of undergraduate engineering degrees and interest in engineering careers.

The overall trend has been fewer students entering engineering (reflecting demographic declines in the college-age population), with a slight upturn in 1997 and 1998 (EWC 1999). At the undergraduate level, the EWC data show a declining trend in enrollment, from a high point of 441,200 students in 1983 to 356,000 students in 1996 (a 19-percent reduction). (See appendix table 4-13.) The decline was neither smooth nor continuous. Engineering enrollment stabilized for several years (1989–92) before resuming its declining trend until 1996. This declining trend turned around slightly in 1997 and 1998, with a 1.5-percent annual increase in undergraduate engineering enrollment. Trends in graduate engineering enrollment differ: graduate enrollment increased from 1979 to 1992 and then declined each year. (See figure 4-9.)

Associate's Degrees

The characteristics of the community college—flexibility, accessibility, links with industry, remediation, and low cost—contribute to its broad appeal. Many students who enroll in two-year colleges are seeking certificates or associate's degrees, but some find two-year colleges an inexpensive means of completing the first two years of a college education before transferring to a four-year institution. About 22 percent of 1989/90 beginning postsecondary students who began at two-year institutions transferred to four-year institutions[8] (NCES 1998a), thereby increasing access to higher levels of education. The majority of community colleges have links with industry; two-year engineering technology programs generally have cooperative programs with industry to train workers (Burton and Celebuski 1995). One-half of commu-

[8]The source of these data is the U.S. Department of Education's Beginning Postsecondary Students Survey, reported in NCES (1998a).

Text table 4-4.
Estimated enrollment in undergraduate mathematics courses

Course level	Four-year institutions 1970	1980	1985	1990	1995	Two-year institutions 1970	1980	1985	1990	1995
	Enrollment (in thousands)									
All math courses	1,188	1,525	1,619	1,619	1,469	555	925	900	1,241	1,384
Remedial	101	242	251	261	222	191	441	482	724	800
Precalculus	538	602	593	592	613	134	180	188	245	295
Calculus	414	590	637	647	538	59	86	97	128	129
Advanced	135	91	138	119	96	0	0	0	0	0
Other	NA	NA	NA	NA	NA	171	218	133	144	160
	Percent									
All math courses	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Remedial	0.09	0.16	0.16	0.16	0.15	0.34	0.48	0.54	0.58	0.58
Precalculus	0.45	0.39	0.37	0.37	0.42	0.24	0.19	0.21	0.20	0.21
Calculus	0.35	0.39	0.39	0.40	0.37	0.11	0.09	0.11	0.10	0.09
Advanced	0.11	0.06	0.09	0.07	0.07	0.00	0.00	0.00	0.00	0.00
Other	NA	NA	NA	NA	NA	0.31	0.24	0.15	0.12	0.12

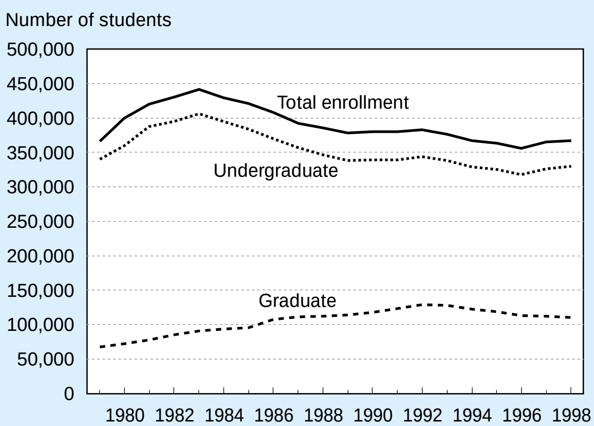
NA = not applicable

NOTE: Precalculus-level mathematics courses include algebra and trigonometry courses, as well as courses for nonscience majors, finite mathematics, non-calculus-based business mathematics, and mathematics for prospective elementary school teachers.

SOURCE: D.C. Rung, "A Survey of Four-Year and University Mathematics in Fall 1995: A Hiatus in Both Enrollment and Faculty Increases," *Notices of the AMS* 44, no. 8 (September 1997): 923–31.

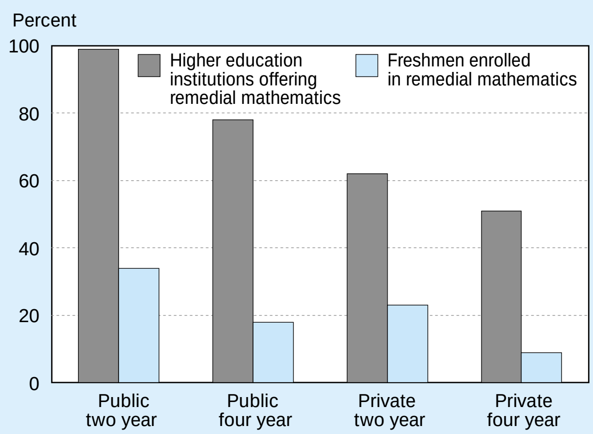
Science & Engineering Indicators – 2000

Figure 4-9.
Engineering enrollment, by level: 1979–98



See appendix table 4-14. *Science & Engineering Indicators – 2000*

Figure 4-10.
Course offerings in remedial mathematics, by type of institution: 1995



See appendix table 4-15. *Science & Engineering Indicators – 2000*

nity college students are enrolled on a part-time basis. Almost all public two-year institutions provide remedial coursework, and approximately one-third of the students in these institutions are enrolled in remedial mathematics courses. (See figure 4-10.)

Since 1990, student enrollment has leveled off in all institution types that produce large numbers of S&E degrees. In contrast, over the past several decades, student enrollment in U.S. higher education institutions has increased most in two-year colleges. These institutions produce relatively few degrees, however. In 1996, 38 percent of the 15 million students in U.S. higher education were enrolled in two-year colleges, but they earned only 500,000 associate's degrees. Among beginning students at two-year colleges in the 1989/90 school year, only 24 percent had earned an associate's or higher degree by 1994 (NCES 1998a). This large disparity between the number of students enrolled and earned degrees implies high attrition rates but also highlights one of the characteristics of community colleges—a large amount of coursetaking for specific skills not necessarily leading to an associate's degree. Part of this lack of persistence in completing an associate's degree is intentional; full-time students, as well as part-time, older, and night school students, may take a sequence of courses for specific skills to enter or change positions in the labor force. For a variety of other reasons, students can earn credentials below the level of associate's degree.

Among those who do earn associate-level degrees, relatively few (11 percent) earn them in S&E or engineering technology fields. In 1986–96, the number of associate's degrees in S&E fields has been modest and quite stable, ranging between 20,000 and 25,000 degrees out of approximately 450,000 to 540,000 total degrees. (See appendix table 4-16.) More numerous, however, are degrees earned in engineering technology programs (approximately 36,000 in 1996). Such engineering technology programs are mainly focused on electronics, computer technology, graphics, and mechanical engineering. (See Burton and Celebuski 1995.)

Although associate's degrees in engineering technology have been declining for about a decade—reaching a low of 36,000 in 1996 (Burton and Celebuski 1995)—enrollment in these programs is far higher than completed degrees would indicate. A survey of technical education in two-year colleges showed that course enrollment was about seven times higher than completed degrees (Burton and Celebuski 1995). The study also showed linkages with local industry that allow enrollees to acquire useful skills and familiarity with science, mathematics, engineering, and technology and join the industrial workforce without completing an associate's degree. Because of the importance of two-year colleges in preparing workers for high-technology employment, more needs to be known about the quality of education being provided and the attrition rates of their students.

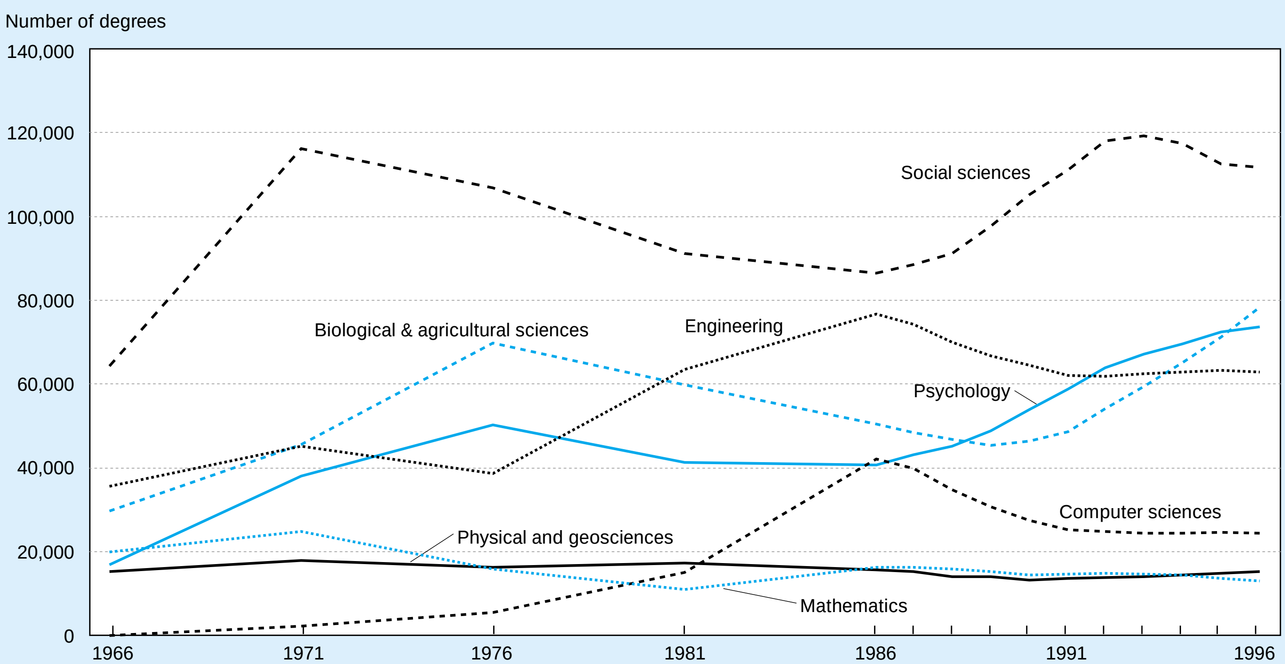
Bachelor's Degrees

Trends in Earned S&E Degrees

Since the 1950s, trends in total S&E degrees earned show continual upward growth, although several fields of NS&E show a declining number of degrees in the 1990s. (See figure 4-11.) The growth occurred in two waves: the first in the 1950s and 1960s and the second in the 1990s (U.S. HEW 1956). The first growth period was the strongest; the number of degrees in S&E fields increased at an average annual rate of eight percent. Then, during the decades of the 1970s and 1980s, the total overall degrees earned fluctuated and increased at an average annual rate of less than 1 percent, followed by a second and milder growth period in the 1990s. S&E degrees at the bachelor's level increased at an average annual rate of 2.6 percent from 1990 to 1996. (See appendix table 4-17.)

The increase seen in overall S&E degrees in the past four decades actually represents divergent trends in various fields.

Figure 4-11.
Bachelor's degrees earned in selected S&E fields: 1966–96



NOTE: Data are in five-year increments for 1966–86, and one-year increments for 1986–96. Geosciences include earth, atmospheric, and oceanographic sciences.

See appendix table 4-17.

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Different fields contributed to the expansion of S&E degrees at different time periods, and several fields show a declining number of degrees in the 1990s. The number of degrees in the physical and mathematical sciences peaked in the early 1970s, slowly declined in the 1980s, and then leveled off in the 1990s. In contrast, engineering and computer science degrees peaked in the mid-1980s, quickly declined, and leveled off in the 1990s. Trends in the biological sciences showed a long, slow decline in earned degrees in the 1980s but a reversal of this trend in the 1990s. The only fields with an increasing number of earned degrees in the 1990s are psychology and the biological sciences.

Curriculum Reform in Undergraduate Education

The Steelman report's concern for improving the quality of undergraduate education has been of recurring national interest and has gained momentum in the past 10 years. Individual faculty, departments, professional societies, and institutions of higher education are increasingly involved in reform to enhance undergraduate teaching and the curriculum in mathematics, the various fields of sciences, engineering, and technology. Since 1992, faculties from 700 institutions of higher education have participated in one or more workshops to strengthen student interest and success in mathematics and science (Project Kaleidoscope 1999). Reforms include, for example, infusing more investigative learning into the curricula, using innovative computer laboratories and learning technologies, increasing undergraduate research experiences, and encouraging interdisciplinary collaboration in team teaching.

Reforms are directed at both science and nonscience majors. Improved introductory and advanced courses that attract and retain science majors seek both to augment the S&E workforce needed in the U.S. economy and to prepare adequate numbers of students for advanced study. Designing successful introductory courses is also aimed at strengthening the understanding of the processes and methods of science for all college students. This broader attention to curricular reform in mathematics and science courses for all students is essential for improving future K–12 teachers, public understanding of scientific issues, and citizen participation in an increasingly technological society. (See sidebar, "Institution-Wide Reform.")

Institution-Wide Reform

Since curricular changes and facility improvements occur slowly without departmental and institutional backing, a major theme of undergraduate education reform in S&E courses is the so-called institution-wide reform. The aim of institution-wide reform is to revitalize undergraduate education on a more comprehensive, self-sustaining, and interdisciplinary basis. Recently initiated assessments of these initiatives will attempt to develop quantitative indicators on faculty, students, and institutions (Ruskus 1999). For example, faculty assessment will include the proportion of S&E faculty revising their curricula for best practices in teaching, collaborating with other faculty in developing courses, and publishing research on improved teaching and learning. Student outcomes will include the proportion of students completing S&E courses that reflect best practices, enrollment in follow-on courses, completion rates for S&E majors, and an undergraduate research experience or internship.

International Comparison of First University Degrees in S&E

Diffusion of Higher Education in S&E Fields

The worldwide expansion in advanced S&E education capabilities is particularly evident in Europe, Asia, and the Americas.[9] One indicator of this diffusion of S&E education capacity is the rapidly increasing number of students completing university degrees in S&E. (See appendix table 4-18 and NSB 1998.) Another indicator is the expansion of doctoral programs in S&E and graduate education reforms to improve the quality of research and build national innovation capacity. (See "International Comparison of Doctoral Degrees in S&E.[10])

In 1997, more than 2.7 million students worldwide earned a first university degree[11] in science or engineering. (Note that the worldwide total includes only countries for which recent data are available, primarily in the Asian, European, and American regions, and is therefore an underestimation.) These 2.7 million degrees are evenly balanced among the broad S&E fields: about 900,000 students earned degrees in each of the broad fields of natural sciences,[12] social sciences, and engineering. (See appendix table 4-18.)

From among reporting countries, more than 1 million of the 2.7 million S&E degrees were earned by Asian students within Asian universities. Students across Europe (including Eastern Europe and Russia) earned more than three-quarters of a million first university degrees in S&E. And students in the North American region earned one-half million bachelor-level degrees. These three regions, Asia, Europe, and North

[9] Data in this section are primarily taken from the National Science Foundation, Science Resources Studies Division, *Global Database on Human Resources for Science*, and are based on national and international sources. (See appendix table 4-18.)

[10] For other indicators of the development of science and technology infrastructure in several world regions, see other chapters in this volume on research and development (chapter 2), bibliometrics (chapter 6), and patents and high-technology trade (chapter 7).

[11] A first university degree refers to completion of an undergraduate degree program. These degrees are classified as level 6 in the International Standard Classification of Education, although individual countries use different names for the first terminal degree: for example, *laureata* in Italy, *diplome* in Germany, *maitrise* in France, and bachelor's degree in the United States and in Asian countries.

[12] The natural sciences comprise the physical, earth, atmospheric, oceanographic, biological, and agricultural sciences; mathematics; and computer sciences.

America, account for the large majority (88 percent) of reported S&E bachelor's degrees earned worldwide. Students in Asia and Europe earn more first university degrees in engineering than in natural sciences and generally more in natural sciences than in social sciences, whereas in North America earned degrees show the reverse. (See figure 4-12 and appendix table 4-18.)

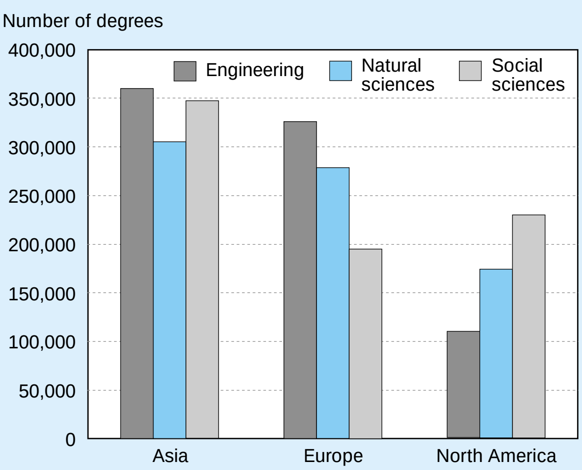
Growth Rates in S&E Fields

The higher growth rate in NS&E degrees in Asia and Europe than in North America has been reported earlier (NSB 1998; NSF 1993; NSF 1996a). For example, in the past decade, the average annual growth rate in earned NS&E degrees in the Asian and European regions was more than 4 percent. In contrast, in the North American region the number of NS&E degrees declined at an average annual rate of 0.9 percent during this same time period.

Trends in Asia

Recent changes in higher education in these regions, however, are less well known. These changes include a leveling off of bachelor-level S&E degrees and a shift in emphasis to doctoral S&E training. (See figures 4-13 and 4-14.) Bachelor-level engineering degrees peaked in Asia in 1995 at 324,500 and declined slightly in 1996. Similarly, natural science degrees peaked at 191,500 in 1995 and dropped slightly in 1996. (See "International Comparison of Doctoral Degrees in S&E" and sidebar, "Graduate Reforms in Europe, Asia, and Latin America.") Bachelor's degrees will again begin to increase around 2003–04, from the large expansion of undergraduate enrollment in China in 1999 (Plafker 1999).

Figure 4-12.
First university degrees in S&E in selected countries, by region: 1997 or most recent year



NOTES: Natural sciences include physical, biological, agricultural, earth, atmospheric, and oceanographic sciences, mathematics, and computer sciences. Social sciences include psychology, sociology and other social sciences.

See appendix table 4-18 for countries included within each region.

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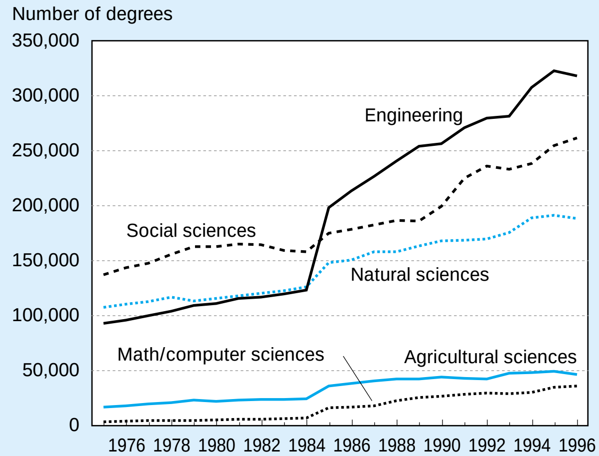
Figure 4-13.
Bachelor's degrees in S&E fields earned within selected Asian countries: 1975–96



NOTES: The steep rise in degrees in 1985 reflects the inclusion of Chinese data from that year on. Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix table 4-19 for Asian countries included.

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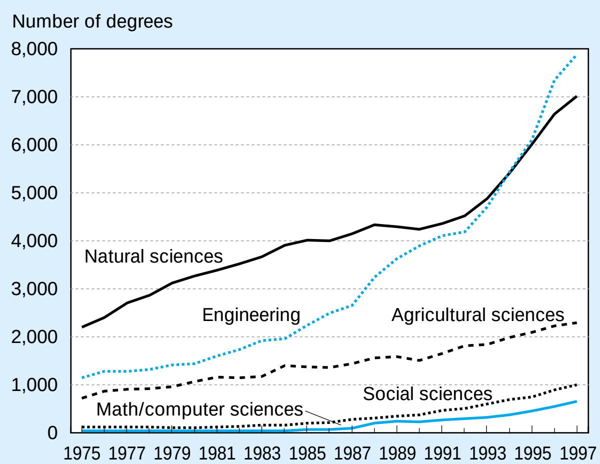
Figure 4-14.
Doctoral degrees in S&E fields earned within selected Asian countries: 1975–97



NOTES: Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix table 4-19 for Asian countries included.

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In addition, Asian countries are reexamining the field mix of sciences within their universities, to balance the previous concentration on physical science and engineering and meet new needs. For example, Japan would like to increase study in the biological sciences and biotechnology for the health research needs of an aging population and for bioengineering industries of the future (see Government of Japan 1998a, 1998b, 1999). Text table 4-5 shows the number of biology and engineering degrees in Japan, their percent of total degrees, and comparative data from the United States. Within Japan, bachelor's degrees earned in the biological sciences are less than 1 percent of total degrees, while engineering degrees represent more than 19 percent of degrees earned at this level. Similarly, large differences exist at the master's and doctoral level. In contrast, in the United States, biology and engineering degrees represent a similar proportion of total degrees at both the bachelor's and doctoral levels. At the bachelor's level, biology and engineering each represent about 5 percent of total U.S. degrees; at the doctoral level, 14 to 15 percent of total degrees.

Trends in Europe

Recent European developments include a continually broadening access to higher education, more mobility for students and faculty among the countries of the European Union, and graduate education reform. European countries are introducing and expanding their short-cycle, three- to four-year undergraduate programs, alongside their traditional universities that require six to seven years for completion of the first university degree (equivalent to a master's). For example, Germany has increased the shorter cycle, four-year undergraduate institutions, called *Fachhochschulen,* and revised first university degree programs to shift more of the research training to the doctoral level (NSF 2000).

Comparison of Proportion of Degrees in S&E and non-S&E Fields Across Countries

How does the U.S. educational system compare with other countries in its emphasis on S&E in undergraduate programs? One indicator of focus on science and engineering is the proportion of degrees earned in S&E and non-S&E fields. Considering total degrees across all regions, the 2.7 million S&E degrees represent 42 percent of all first university degrees. (See appendix table 4-20.) However, some countries emphasize S&E fields in higher education more than others do. In several large countries—Japan, Russia, and Brazil—students earn more than 60 percent of their first university degrees in S&E fields, and in China, 72 percent do. In contrast, in the United States, students earn their degrees in a wide range of S&E and non-S&E fields: U.S. students earn about one-third of their bachelor-level degrees in S&E fields, mainly in the social sciences. (See appendix table 4-20.)

Of the first university degrees across all regions, approximately 14 percent are earned in each of the broad fields of natural sciences, social sciences, and engineering. There are strong differences in field emphases across countries, however. Engineering represents 46 percent of the earned

Text table 4-5.
Earned degrees in biology and engineering in U.S. and Japanese universities, by level: 1996

Country and field	Bachelor's Total	Bachelor's Men	Bachelor's Women	Master's Total	Master's Men	Master's Women	Doctoral Total	Doctoral Men	Doctoral Women
Number									
United States									
Total, all degrees	1,179,815	528,000	651,815	408,932	180,360	228,572	42,415	25,470	16,945
Engineering	63,114	51,798	11,316	27,763	23,009	4,752	6,305	5,529	776
Biology	62,081	29,216	32,865	6,286	2,945	3,341	5,723	3,308	2,415
Japan									
Total, all degrees	512,814	341,116	171,698	47,747	38,022	9,725	8,968	7,477	1,491
Engineering	99,428	92,097	7,331	22,622	21,454	1,168	2,127	2,016	111
Biology	1,875	1,139	736	794	572	222	192	159	33
Percent									
United States									
Total, all degrees	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Engineering	5.3	9.8	1.7	6.8	12.8	2.1	14.9	21.7	4.6
Biology	5.3	5.5	5.0	1.5	1.6	1.5	13.5	13.0	14.3
Japan									
Total, all degrees	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Engineering	19.4	27.0	4.3	47.4	56.4	12.0	23.7	27.0	7.4
Biology	0.4	0.3	0.4	1.7	1.5	2.3	2.1	2.1	2.2

SOURCES: National Science Foundation, Science Resources Studies Division, *Science and Engineering Degrees 1966–96*, NSF 99-330, Author, Susan T. Hill (Arlington, VA: 1999); Government of Japan, Ministry of Education, Science, and Culture (Monbusho), *The Monbusho Survey of Education* (Tokyo: annual series, 1996).

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bachelor's degrees in China, about 30 percent in Sweden and Russia, and about 20 percent in Japan and South Korea. In contrast, students in the United States earn only 5 percent of bachelor-level degrees in engineering fields. Countries with high concentration of university degrees in the natural sciences include Ireland (34 percent), France and India (20 percent), and the United Kingdom (18 percent). (See appendix table 4-20.)

Participation Rates in University Degrees and S&E Degrees

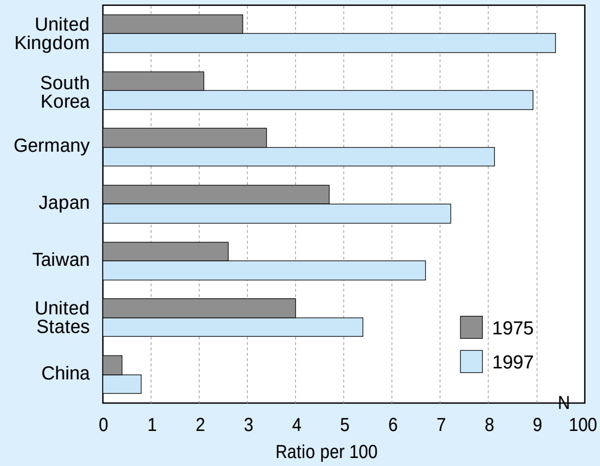
The concern raised by the Steelman report regarding the need to prepare a sufficient number of students for advanced graduate education and research in science not only has remained of national interest but has broadened. The issue has been broadened from ensuring adequate numbers of students willing and able to enter graduate S&E programs to preparing all citizens for life and employment in a high-technology economy. A high ratio of the college-age population earning university degrees correlates with better public understanding of science, and a high proportion of the college-age population earning an NS&E degree is an indicator of the technical skill level of those entering the workforce.

The ratio of U.S. bachelor's degrees to the college-age cohort is relatively high: 32 per hundred. Only a handful of countries (the United Kingdom, Canada, Australia, and New Zealand) have higher ratios. However, the ratio of NS&E degrees to the college-age population in more than a dozen Asian and European countries is higher than in the United States. South Korea and Taiwan dramatically increased their ratio of NS&E degrees to their 24-year-olds, from 2 per hundred in 1975 to 7 per hundred in 1997 in Taiwan and 9 per hundred in South Korea. Japan has maintained a high ratio of NS&E degrees to its 24-year-old population since the 1970s, with a slight decline in the late 1980s. The higher ratios after 1995 reflect an increasing number of NS&E degrees and the declining college-age population in Japan. Their college-age cohort will continue to decline until 2010. (See appendix table 4-18 for 1997 data and NSF 1993 for trend data on Asian countries, and appendix table 4-7 for the trends on declining college-age cohorts of major industrialized countries.)

Asia's two giants, India and China, have low participation rates in NS&E degrees. India, with its huge, growing population, is maintaining its participation rate of 1 per hundred. China, with an even larger population, has doubled its participation rate in the past decade, from 0.4 per hundred in 1985 to 0.9 per hundred in 1996. (See NSF 1993 for trend data, figure 4-15 and appendix table 4-18.)

A declining pool of college-age students in Europe has not resulted in declining numbers of NS&E degrees as in the United States. The size of the college-age cohort in Europe has declined 21 percent, from 29.7 million in 1985 to 23.5 million in the year 2000.[13] (See appendix table 4-7.) Among European countries, participation rates in NS&E degrees have

Figure 4-15.
Ratio of NS&E degrees to the 24-year-old population, by country



NOTES: The ratio is the number of natural science and engineering degrees to the 24-year-old population, on a scale of 1 to 100. China's data are for 1985 and 1996. Other countries' data are for 1975 and 1997.

SOURCES: National Science Foundation, Science Resources Studies Division (NSF/SRS), *Human Resources for Science and Technology: The Asian Region,* NSF 93-303 (Washington, DC: 1993); NSF/SRS, *Human Resources for Science and Technology: The European Region,* NSF 96-319 (Arlington, VA: 1996); and appendix table 4-18.

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grown to more than offset the declining population, most notably in Germany and the United Kingdom. For example, the ratio of NS&E degrees to the German college-age cohort has increased from 3 per hundred to more than 8 per hundred in the past 20 years. Similarly, in the United Kingdom, the ratio increased from 3 to more than 9 per hundred in this same time period. (See NSF 1996a and appendix table 4-18.)

In contrast, overall participation rates have remained relatively constant in the United States; the ratio of NS&E degrees to the college-age population has remained between 4 and 5 per hundred for the past three decades. That is, students do not show less interest or achievement in earning natural science or engineering degrees; neither do they show more. Demographics have changed significantly, however. As discussed in "Demographics and U.S. Higher Education," the U.S. college-age population decreased by 21 percent from 1980 to 2000. (After this 20-year decline, the U.S. college-age cohort will begin to increase in 2001.) The effect of this demographic trend is partially offset by increasing participation rates for women and underrepresented minorities. Although the decreasing size of the college-age cohort resulted in a downturn in the number of degrees in several NS&E fields, fields in which women are very highly represented (biological sciences and psychology) have produced increasing numbers of degrees in the 1990s. (See appendix table 4-17.)

[13]The European college-age cohort will begin to increase again in 2005.

Graduate S&E Students and Degrees in the United States

One of the indicators of national innovation capacity and potential international competitiveness is the size and growth of graduate programs in S&E (Porter 1999). This acknowledgment of the importance of education to economic growth is prompting countries to reform and expand graduate education. (See sidebar, “Graduate Reforms in Europe, Asia, and Latin America.”)

Trends in Graduate Enrollment

The long-term trend of increasing enrollment in U.S. graduate programs of S&E persisted for more than four decades, followed by four years of declining enrollment, since 1993. The increase in enrollment occurred in two strong waves, reached a peak in 1993, and then subsequently declined in several S&E fields: natural sciences, social sciences, and engineering. (See appendix table 4-21.) The first wave of increasing graduate student enrollment began in the late 1950s and continued throughout the 1960s, with particularly strong Federal support for physics and engineering education and research. The second wave of increasing enrollment occurred in the late 1980s with strong Federal support for academic R&D. (See chapter 2.) A large influx of foreign students into U.S. graduate S&E programs also occurred in the late 1980s. (See appendix table 4-22.) Graduate S&E enrollment more than tripled, from approximately 140,600 students in 1963 (U.S. HEW 1963) to 435,900 in 1993, representing a 2-percent average annual increase over this period.[14] The subsequent drop in the number of graduate S&E students, from 1993 to 1997, represented an average annual decline of 2 percent. (See appendix table 4-21.)

However, the time period and intensity of growth and subsequent declines differ for various fields. Graduate enrollment in the social sciences grew in the 1960s and 1970s, dipped in the early 1980s, and then had a decade-long sharp increase until the mid-1990s. Recent slight decreases in enrollment began in 1995 in psychology and in 1997 in the social sciences. (See appendix table 4-21 and NSF 2000.)

Enrollment in the natural sciences, on the other hand, accelerated in the 1960s, echoing sharp increases in physical sciences support from several government agencies (National Aeronautics and Space Administration, Department of Defense, and Department of Energy), followed by modest growth from 1975 to 1990. The subsequent rapid growth in the early 1990s correlated with expanded research support in the biological sciences. Recent declines in enrollment in the natural sciences, however, are mainly from fewer students enrolling in physical and biological sciences. (See appendix table 4-21 and NSF 2000.)

[14]The graduate student enrollment survey used by the U.S. Department of Health, Education, and Welfare in 1963 and that used by the National Science Foundation in 1993 have slightly different base populations, so only approximate comparisons can be made between the number of graduate students in these two periods.

Engineering followed an upward growth trend until 1992, with declining enrollment every year since then. Both U.S. and foreign students contributed to the rather sharp increase in engineering from 1986 to 1992; the decline since 1993 has been based on fewer U.S. and foreign students entering graduate engineering programs. (See appendix tables 4-21 and 4-22.)

Graduate enrollment in mathematics and computer sciences grew rapidly from 1980 to 1986, similar to engineering, with more modest growth until 1992, followed by a leveling off and slight decline (in mathematics). Foreign students accounted for much of the growth in the 1980s. The favorable U.S. job market after 1992 may account for some of the decline in graduate enrollment. (See appendix table 4-21 and 4-22 and NSF 1999a for disaggregated data on mathematics and computer sciences.)

Master’s Degrees

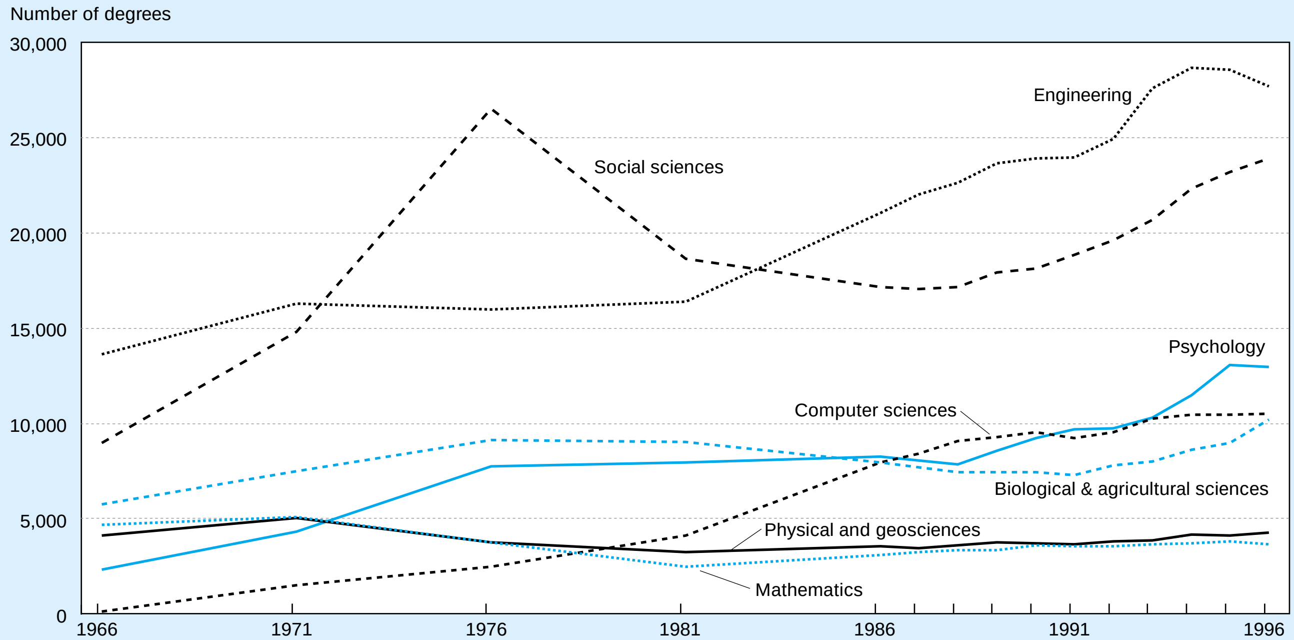
Although graduate enrollment in S&E programs contracted in 1994, master’s degrees in S&E continued to increase through 1996. (See appendix tables 4-21 and 4-23.) In fact, increases in S&E degrees at the master’s level persisted for more than four decades, with accelerated growth in the first half of the 1990s and a leveling off in 1996. Master’s degrees expanded from the modest number of 13,500 in 1954 to more than 95,000 in 1996.

At the master’s level, growth in the number of students earning degrees occurred at different times for different fields. The increase in degrees in the physical and mathematical sciences peaked in the early 1970s and then declined, whereas growth in computer sciences continued to increase throughout the 1980s and 1990s. The number of earned degrees in the social and behavioral sciences peaked in the late 1970s, declined for more than a decade, and then showed a reversal of this trend in 1989 with continual annual increases. Biological and agricultural sciences followed this same pattern of a peak in the late 1970s and declined until 1990. Since then, agricultural sciences have increased even more sharply than the biological sciences (NSF 1999b). Engineering, on the other hand, has had almost continual growth over more than four decades, with slight declines in both 1995 and 1996. (See figure 4-16 and appendix table 4-23.)

Doctoral Degrees

The Steelman report’s recommendation to train scientists and engineers in all fields of knowledge has been carried out. Doctoral S&E degree production in U.S. universities shows two waves of strong growth in the last half of the 20th century. The first upsurge of doctoral S&E degrees in the late 1950s and 1960s reflected the Cold War and the space race, as well as the result of the wave of GIs taking S&E-oriented bachelor’s programs following World War II. (See appendix table 4-24.) This buildup of doctoral programs was followed by a long, slow decline in NS&E fields beginning in the early 1970s (from the cutback in the space program) and in the social sciences in the 1980s. In the 1980s, the second wave of growth occurred in NS&E fields with large increases in aca-

Figure 4-16.
Master's degrees awarded in S&E, by broad field: 1966–96



NOTES: Data are in five-year increments for 1966–86, and one-year increments for 1986–96. Geosciences include earth, atmospheric, and oceanographic sciences.

See appendix table 4-23. *Science & Engineering Indicators – 2000*

demic R&D budgets. (See appendix table 4-25 and chapter 6.) From 1986 to 1992, increasing numbers of foreign students entered these expanded graduate NS&E programs. (See appendix table 4-26.)

Within the natural sciences, doctoral degrees in the biological and agricultural sciences had a long, steady, upward trend from 1970 to 1997, while degrees in the physical sciences peaked in the late 1960s, declined to 1980, grew quite steadily to 1995, and then leveled off. (See figure 4-17.) Doctoral degrees earned in the social sciences show a continual steady increase throughout the 1990s. The slight drop in doctoral degrees in NS&E fields in 1997 is mainly accounted for by the decline in the number of foreign doctoral recipients in that year. (A decline in foreign graduate enrollment in U.S. universities occurred from 1993 to 1996.) (See "Diversity Patterns in S&E Enrollment and Degrees in the United States" for doctoral degrees by race/ethnicity and citizenship.)

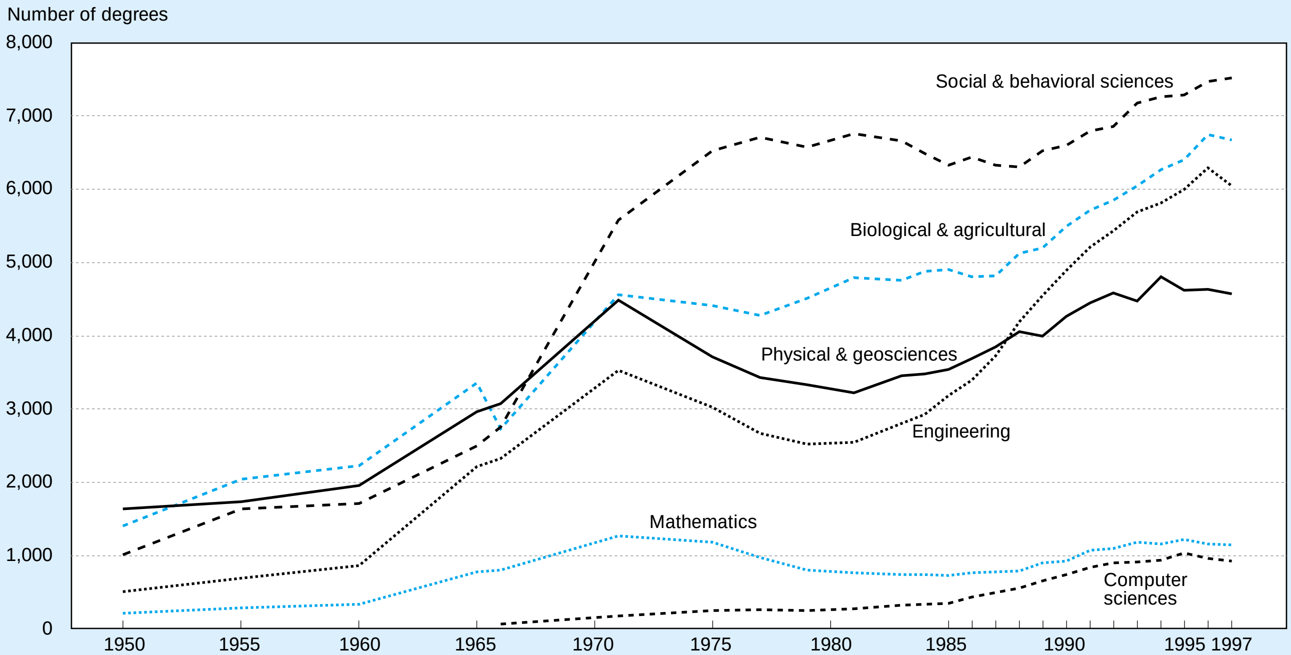
Steelman's concern for creating the "right" number of S&E doctorates to meet the needs of the workplace relates to the current issue of "overproduction" of doctoral degrees. The "right" number remains elusive. Attempts to model the complexity and change in the U.S. economy and predict demand for doctoral-level personnel by specific S&E fields have been unsuccessful. Rather than attempting to forecast demand or the "right number" of S&E doctorates, policymakers are recommending doctoral education that broadens career options. Because a larger proportion of S&E doctoral recipients than ever before have to seek employment outside academia (COSEPUP 1995), reforms are directed to broadening doctoral education for employment skills both within and beyond academia. (See sidebar, "Graduate Reforms in Europe, Asia, and Latin America.") For example, one large effort for better preparing doctoral students for teaching careers is "The Association of American Colleges and Universities' Preparing Future Faculty program." In addition, NSF has established Engineering Research Centers that provide more interdisciplinary learning and collaboration with industry for engineering students. (See the NSF Web site <<www.eng.nsf.gov/eec/erc.htm>>.)

International Comparison of Doctoral Degrees in S&E

The scale of doctoral programs has increased in several world regions, particularly Europe, Asia, and the Americas. This capacity building in doctoral S&E education is linked to national policies to develop an S&E infrastructure that more explicitly links universities to innovation and economic development. (See sidebar, "Graduate Reforms in Europe, Asia, and Latin America." at the end of this section.) By broad world region,[15] Western Europe produces more doctoral S&E degrees than North and South America (the Americas) and Asia.

[15]This discussion of international comparisons presents data in terms of three world regions—Asia, Western Europe, and North America. The specific countries composing these regions are listed in appendix table 4-27.

Figure 4-17.
Doctoral S&E degrees earned in U.S. universities, by field: 1950–97



NOTES: Data are in five-year increments for 1950–85, and one-year increments for 1985–97. Geosciences include earth, atmospheric, and oceanographic sciences.

See appendix tables 4-24 and 4-25.

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In 1997, doctoral degrees awarded in S&E fields by Western European institutions totaled 40,000—about one-fifth higher than the number of such degrees earned in the American region and more than twice as many as the number recorded for Asian countries. (See appendix table 4-27 and figure 4-18.)

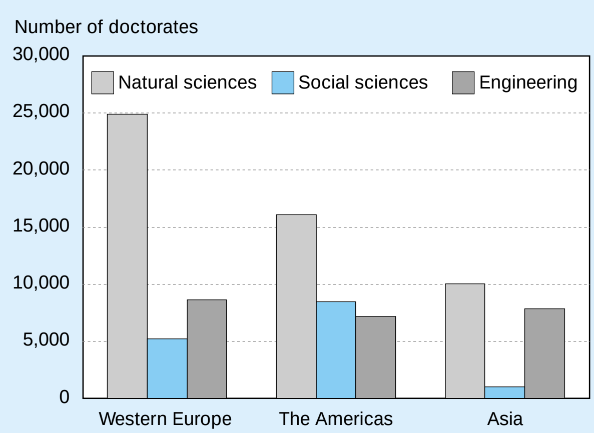
Considering broad fields of science, the largest number of natural science doctorates are earned within Western European universities, while the largest number of social science doctorates are earned within universities in the Americas. In contrast, in engineering, each region produces about one-third of the doctoral-level degrees.

Trends in Doctoral Degrees—Europe and the United States

By individual country, the United States has the highest number of doctoral degrees earned in S&E fields. In 1997, U.S. universities awarded about 27,000 S&E doctoral degrees—more than twice the number of S&E degrees awarded in any of the other major industrial countries. (See figure 4-19.) However, the combined doctoral S&E degrees of the three largest European countries (Germany, France, and the United Kingdom) recently surpassed the number of U.S. earned degrees. (See figure 4-19.)

S&E doctoral degrees in Germany grew faster than non-S&E doctoral degrees between 1975 and 1997. The number of S&E degrees increased 4.3 percent annually, engineering increased 5.0 percent annually, and non-S&E doctoral degrees increased 2.8 percent annually during this 22-year period. (See appendix table 4-28.) France undertook a reform of doctoral

Figure 4-18.
Doctoral S&E degrees by region and field: 1997



NOTES: Natural sciences include physical, biological, agricultural, earth, atmospheric, and oceanographic sciences, mathematics, and computer sciences. Social sciences include sociology, psychology, and other social sciences.

See appendix table 4-27 for countries included within each region.

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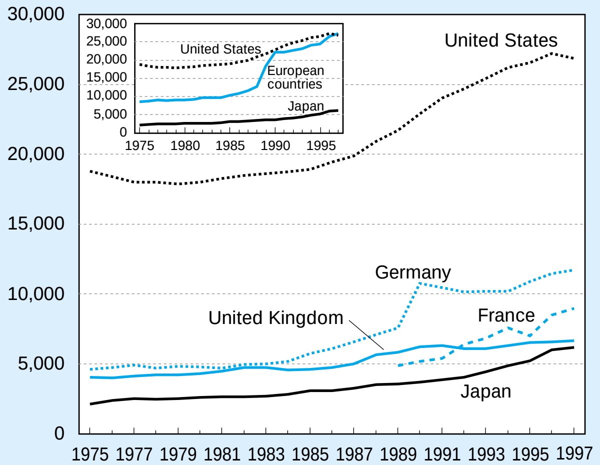
Figure 4-19.
Doctoral S&E degrees in selected industrialized countries: 1975–97



NOTES: The peak in the data from Germany in 1990 reflects the inclusion of degrees from former East Germany beginning in that year. The inset combines the three European countries.

See appendix table 4-28. *Science & Engineering Indicators – 2000*

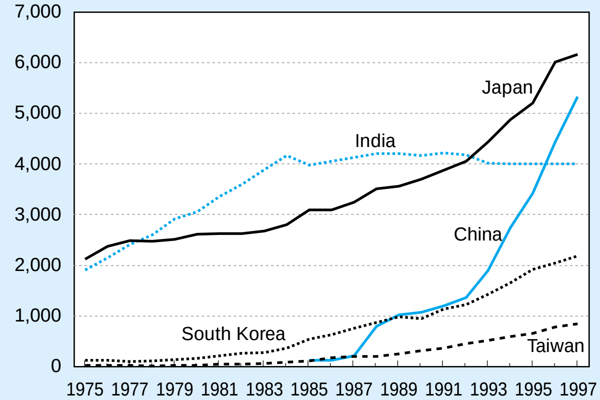
studies in 1988 in an effort to double the number and improve the quality of S&E doctoral degrees awarded within eight years. The effort has largely succeeded: the number of S&E doctoral degrees awarded in France increased from 5,000 in 1989 to 9,000 in 1997—more than an 83-percent increase (Government of France 1998a). In contrast to Germany, doctoral S&E degrees in the United Kingdom have not grown as fast as non-S&E doctoral degrees: S&E doctoral degrees grew 2.6 percent annually in the past two decades, while non-S&E fields grew 5.0 percent annually.

Trends in Doctoral Degrees—Asia

The scale of graduate education in Japan has been small by international standards. Until recently, most doctorates in NS&E in Japan were earned by industrial researchers after many years of research within Japanese companies. Doctoral reforms of 1989 called for the expansion and strengthening of graduate schools and the establishment of a new type of university exclusively for graduate study. The government has sharply increased support to universities to improve facilities and accelerate doctoral programs in NS&E fields. In 1994, Japanese engineers earned more doctoral degrees for research within university laboratories than within industrial research laboratories—53 percent and 47 percent, respectively (NSF 1997).

Asian graduate education reforms are also strengthening and expanding doctoral programs in China, Taiwan, and South Korea. (See figure 4-20.) In 1997, S&E doctoral degrees earned within major Asian countries (China, India, Japan, South Korea, and Taiwan) reached more than 18,000, representing a 12-percent average annual increase from 1993 to 1997. In contrast, such degrees earned by Asian students (from these five countries) within U.S. universities peaked at 6,900 in 1996 (representing less than a 5-percent average annual growth rate from 1993 to 1996) and declined in 1997. (See figure 4-21.)

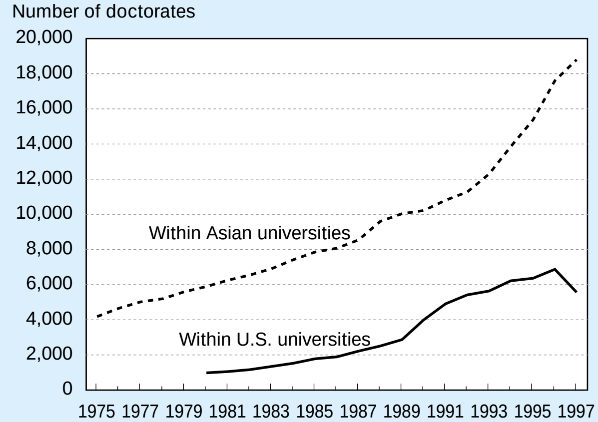
Figure 4-20.
Doctoral S&E degrees in selected Asian countries: 1975–97



See appendix table 4-29. *Science & Engineering Indicators – 2000*

China has invested heavily in graduate education to "embrace the era of knowledge economy" (*Nature* 1998). While still using the U.S. higher education system to absorb the rising demand for graduate education, Chinese universities have expanded graduate education to be able to absorb a larger proportion of the students seeking advanced S&E degrees. Although the number of S&E doctoral degrees earned by Chinese students within U.S. universities showed a decade-long increase until 1996, the number of such degrees earned

Figure 4-21.
Doctoral S&E degrees earned by Asian students within Asian and U.S. universities: 1975–97



See appendix table 4-30 for Asian countries included.
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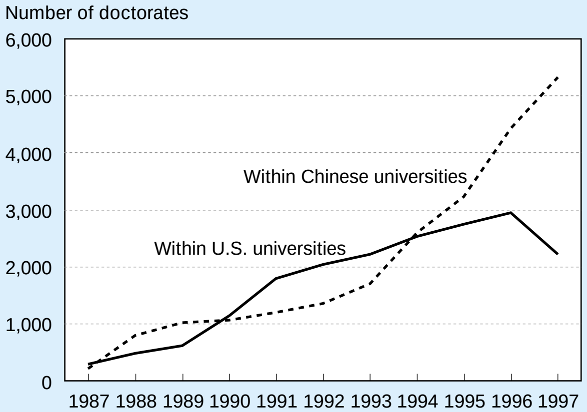
within Chinese universities continues to increase, and at a faster rate. (See figure 4-22.) By 1997, Chinese students earned more than twice as many S&E doctorates within Chinese universities as within U.S. universities.

Other Asian countries are also increasing their capacity to provide S&E graduate education. In the 1980s, the Korean Advanced Institute of Science and Technology was established to increase support for postgraduate training within the country. South Korean universities awarded almost 2,200 doctoral degrees in S&E in 1997, up from 945 such degrees in 1990. (See appendix table 4-29.) More recently, South Korea announced its plan, called "Brain Korea 21" to further strengthen graduate education in the natural sciences and provide university research funds for interdisciplinary programs such as biotechnology and materials science (Baker 1999).

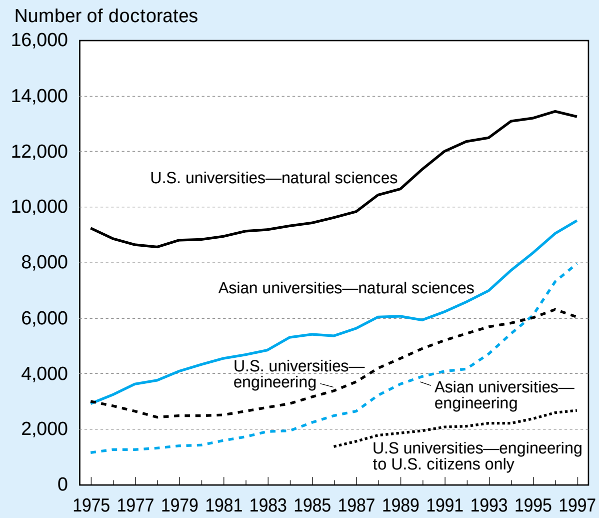
Universities within five Asian countries are now producing more engineering doctorates than universities within the United States. The gap is even larger, since half of the U.S. degrees are earned by foreign students, the majority of whom are Asian. (See figure 4-23.)

Figure 4-22.
Doctoral S&E degrees earned by Chinese students within Chinese and U.S. universities: 1987–97



See appendix table 4-31. *Science & Engineering Indicators – 2000*

Figure 4-23.
Doctoral NS&E degrees earned within U.S. and Asian universities: 1975–97



See appendix tables 4-25, 4-26, and 4-29 for Asian countries included.

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Graduate Reforms in Europe, Asia, and Latin America

As the world's countries recast themselves as "knowledge-based" economies and attempt to build up "national innovation systems,"* interest in doctoral education—particularly in S&E—is increasing around the globe, occasioning a reexamination of its aims and structure. Reforms in doctoral programs in Asia, Europe, and the Americas are aimed at similar concerns—to strengthen and expand doctoral education and to develop the capacity for high quality or "breakthrough" research that would lead to technological innovation. No national assessments are available on how graduate reforms are improving economic competitiveness. There are, however, initial indicators of S&E capacity building: contributions to the world's scientific literature (see chapter 6) and patents and high-technology trade (see chapter 7). Forces for graduate education expansion and reform include demographic, economic, technological, and social changes.

*See, for example, recent journal articles on economic development through S&T by a member of the German parliament (Merkel 1998), by the French Minister of Education (Allègre 1998), and by the Chinese State Science and Technology Commission (*Nature* 1998).

Forces for Change

Demographic

Recruitment pools for graduate education are rising from the so-called massification of higher education programs in industrialized countries (that is, the enlargement of the proportion of the population that undertakes a university degree). Across Europe, participation rates of the college-age cohort in first university degrees have more than doubled in the past 20 years, from 7 to 17 percent. Japan has more than one-quarter of its young people completing bachelor's degrees, and the United States about one-third.

Economic

Among economic forces for reform in the United States and Europe are pressures from national and state funding sources and industry to produce graduate students who are better trained to contribute to economic development. In addition, students are demanding career information and broader skills for employment beyond academia. Asian countries—given their conviction that economic growth is dependent on S&T knowledge and its connection to production—are accelerating their within-country capacity to educate scientists and engineers at the doctoral level.

Technological

The pace of technological change is increasing in industrial R&D, and incremental improvement of products and processes (a particularly strong suit of Japanese industrial labs) is sometimes rendered ineffective by breakthrough innovations creating new commercial products. As current products and processes become obsolete more quickly, industries are motivated to partner with each other and with graduate research programs that augment their innovation capacity. Many inventions are increasingly linked to public science conducted in universities and national laboratories, and industry is increasing its investment in basic research performed in universities. Although still a small proportion of the total, industry is investing in graduate education to have access to some of the best students and encourage them into industrial careers.

Social

The growing demand for public accountability of governmental and academic institutions is forcing the introduction of assessments into higher education. Assessments are directed toward the quality of research and teaching, a reexamination of the balance between faculty research and teaching, the role of graduate students as research assistants, and how the mode of graduate support might affect the breadth of graduate education and the time to degree.

Different Emphases in Reforms Across Countries

Latin America

Within Latin America, countries such as Mexico, Chile, and Argentina have only recently begun to expand the scale of their doctoral programs. (Brazil greatly expanded the scale of its graduate programs in the 1980s to foster graduate S&T programs as a key instrument for knowledge creation and dissemination.) These developing Latin countries are motivated by a desire to have more of their university faculty trained at the doctoral level. For example, within Mexico, about 80 percent of the higher education faculty have only a first university degree (NSF 2000).

Europe and the United States

The criticism by industry of traditional graduate programs as too long, too narrow, and too campus-centered is particularly expressed in the United States, France, and Germany. With the expansion of graduate education and an ever-greater percentage of students who enter careers outside academia, the larger labor market is demanding broader training. For example, Germany is discussing shortening the time to degree and orienting doctoral recipients to industrial research, because doctoral recipients are considered too old to begin working in industry.

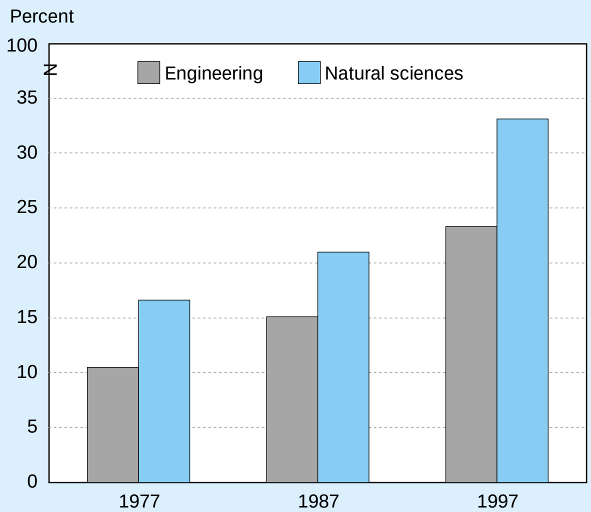
Within Europe and the United States, discussions of reform for broadening doctoral programs include providing off-campus internships and opportunities for interdisciplinary research experience, teaching skills to prepare future faculty, and increasing awareness of career opportunities in industrial research and management. Reforms also relate to lessening time-to-degree and to restraining costs from public funding sources of enlarged graduate programs. Within the United States, lessening time-to-degree is discussed more in terms of institutional accountability and varies by field.

Asian Countries

Within Asian developing countries, reforms are motivated by the belief that universities could be the engines of economic growth through research and innovation leading to high-technology products. Reforms are focused on establishing quality graduate schools, building university facilities and research infrastructure, and acquiring highly trained S&E professors, either at home or abroad. These attempts to expand graduate education and improve its quality are more accelerated in Asia than in Latin America and involve the building of whole new S&T universities. In Chinese Hong Kong and in South Korea, the establishment of S&T universities has been supported primarily by private industry. Chinese (People's Republic) research universities are expanding through more self-support from close alliances with, or ownership of, high-technology industries and through international loans (NSF 2000).

In Japan, industry for the most part had traditionally trained its own doctorate-level researchers. Japan is now concerned that such industrially trained scientists and engineers are not contributing breakthrough research for new and emerging industries. Japan is convinced that industries of the 21st century will require within-country or domestic innovation capacity. As part of its efforts to support future innovation through basic science, Japan is greatly expanding and reforming graduate education within its universities. By 1997, about one-third of Japanese students entered graduate school directly after completing a bachelor of science degree. (See figure 4-24.) Increased allocations for doubling the government's science budget are on schedule and will go mainly to universities to improve the environment for basic research. Institutional changes such as the integration of the Science and Technology Agency and the Ministry of Education (Monbusho) are also a response to this needed reform. Japan is greatly augmenting fellowships and traineeships for graduate students, and funding top-level foreign researchers to come to Japanese universities to upgrade basic research.

Figure 4-24.
Japanese students entering graduate school directly after completing bachelor of science degrees



SOURCE: Government of Japan, Ministry of Education, Science, and Culture (Monbusho), *Monbusho Survey of Education, 1998* (Tokyo: annual series). *Science & Engineering Indicators – 2000*

Diversity Patterns in S&E Enrollment and Degrees in the United States

The Steelman report recommended full utilization of human resources for science but did not explicitly address issues of equity for women and minorities entering S&E fields. As these groups now make up the majority of the labor force, their equal entry into S&E fields is of current national interest.

Enrollment in Undergraduate Programs, by Race/Ethnicity and Sex

Beginning in 1984 and lasting almost a decade, undergraduate enrollment in U.S. institutions of higher education showed strong growth, peaking in 1992 with nearly 12.7 million students. Undergraduate enrollment declined slightly each year until 1995 and leveled off in 1996. The decline is mainly from the decrease in the college-age cohort of the majority (white) population. White enrollment in undergraduate education leveled off in the early 1990s and has declined each year since 1992 for males and females, while enrollment for all minority groups increased. (See appendix table 4-32.)

This trend of increasing enrollment in undergraduate programs by underrepresented minorities has persisted over a decade. Black enrollment increased 3 percent annually from 1.1 million in 1990 to 1.4 million in 1996. Black males have had more modest gains than black females. In the same period, Hispanic enrollment in higher education increased at an even faster rate (7.7 percent) annually. The strongest growth, however, has been among Asians/Pacific Islanders (8.0 percent annually). Undergraduate enrollment of foreign students grew very modestly in the past two decades; in 1996, foreign students still represented only 2 percent of total undergraduate enrollment. (See appendix table 4-32.)

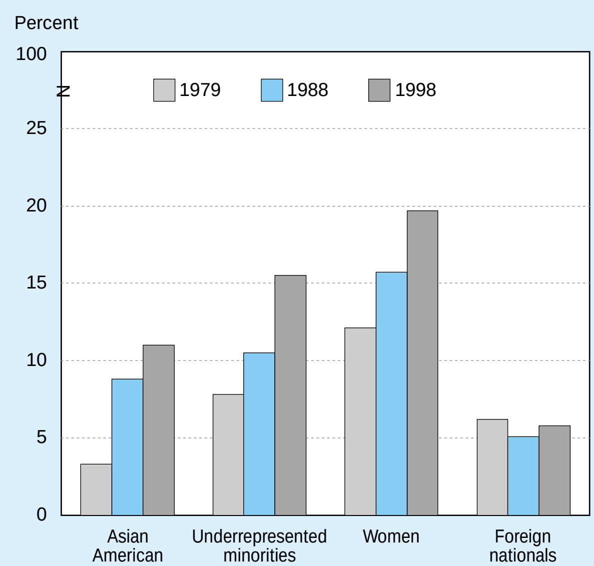
Enrollment in Engineering, by Race/Ethnicity and Sex

While total undergraduate engineering enrollment declined from 1983 to 1996, underrepresented minorities continually increased their enrollment during this period, and female students increased from 1987 to 1998. Female students enrolled in engineering increased from 60,000 in 1987 to 72,000 in 1998. For underrepresented minorities, the increases were greater over a longer period, from 37,000 in 1983 to almost 57,000 in 1998. (See appendix table 4-33.) By 1998, female students represented 19.7 percent of total undergraduate engineering enrollment, and underrepresented minorities represented 15.5 percent of such enrollment. (See figure 4-25.)

Persistence Toward a Bachelor's Degree, by Sex and Race/Ethnicity

There is a considerable gap between enrollment in S&E programs and successful completion of S&E degrees. National longitudinal data with high school and college transcripts provide some indicators of retention in S&E fields, as well as students' exploration and switching to other academic departments in undergraduate education. The Beginning Postsecondary Students (BPS) Longitudinal Study analyzed

Figure 4-25.
Representation of women and minorities in undergraduate engineering enrollment



See appendix table 4-33. *Science & Engineering Indicators – 2000* completion rates of all beginning students in college, including nontraditional (older) students as well as traditional students (NCES 1996). The analysis on completion rates presented in *Women and Men of the Engineering Path* was restricted to engineering students who had reached the threshold of completing three required engineering courses (USDE 1998). Based on these national surveys, this section provides summary findings on differences in completion rates by race and sex.

Persistence in S&E majors of beginning college students can be examined, by race/ethnicity and sex, through the BPS of 1989/90 and 1995 follow-up. The transcripts of a subsample of 926 students who enrolled in S&E programs their freshmen year were examined over the next five years to identify the following outcomes: the proportion that completed a degree in an S&E field, those who still persisted in studying toward such a degree, students who switched to non-S&E fields, and those who dropped out of college. These data showed that less than one-half of the students intending an S&E major from any racial/ethnic group completed an undergraduate S&E degree within five years.[16] Further, females were more likely than males to complete an S&E degree within five years. In addition, about 22 percent of students from all racial/ethnic groups dropped out of college within five years.

[16]The completion rate is somewhat higher for all fields of study, not just S&E fields. Among beginning students seeking bachelor's degrees in 1989/90, 57 percent of those who began in four-year institutions completed a bachelor's degree in five years (see NCES 1996 for completion rates by enrollment status).

Besides completions and dropouts, the study further showed the considerable percentage of students (16 percent to 27 percent) who persist in studying S&E fields five years after entering and the percentage who have explored and switched to other fields. The study found that, compared with the white and Asian/Pacific Islander groups, fewer underrepresented minority students completed an S&E degree within five years, but a higher percentage were still persisting in studying for an S&E degree. In addition, a higher percentage of underrepresented minority students switched to non-S&E fields. (See figure 4-26.)

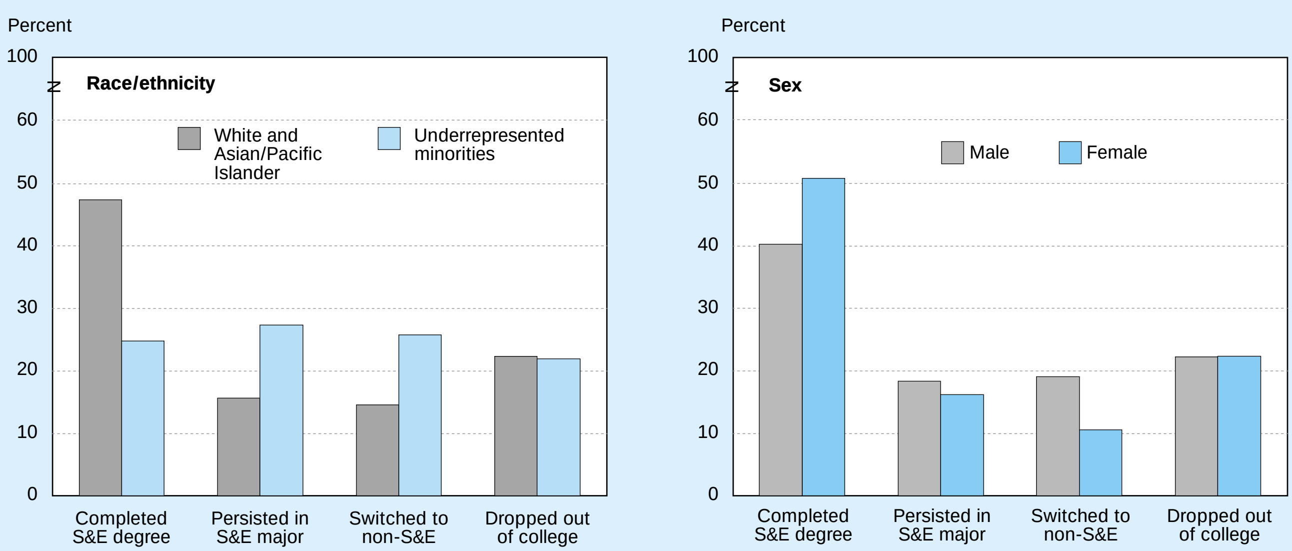
An analysis of persistence in engineering reported in *Women and Men of the Engineering Path*[17] found that, of those students who reached the threshold of the engineering path (had completed three required engineering courses),[18] 59 percent earned a bachelor's degree in engineering by age 30. The analysis used an 11-year transcript history 1982–93 of the High School and Beyond/Sophomore Cohort Longitudinal Study.[19] The study found that women have a 20-percentage-point gap in their completion rate of undergraduate engineering programs: a 62-percent completion rate for males and 42 percent for females (USDE 1998).

[17]See the full study (USDE 1998) for the contents of the engineering core curriculum, secondary school background characteristics of those who reach the threshold, the "curricular momentum" of mathematics and science courses in high school and college for those who enter and complete engineering degrees, various institutional attendance patterns, field migration, classroom environments, and the role of community college.

[18]Approximately 9 percent of all freshmen reach the threshold of the engineering path.

[19]The study used a representative sample of more than 8,000 students.

Figure 4-26.
Completion and attrition rates five years after beginning an S&E major, by race/ethnicity and sex



SOURCE: National Center for Educational Statistics (NCES), Beginning Postsecondary Student (BPS) Longitudinal Study (Washington, DC: 1996). (Based on subsample of 926 first-year S&E students in 1990 and 1995 follow-up.)

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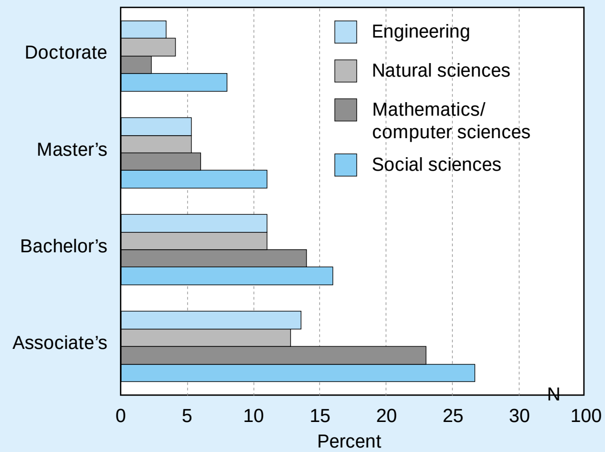
Associate's Degrees

Students from underrepresented minority groups earn a higher proportion of their S&E degrees at the associate's level than in four-year or graduate programs. In 1996, these students earned about 23 percent of the mathematics and computer science degrees at the associate's level, a far higher percentage than at the bachelor's or advanced levels of higher education. At advanced levels of higher education, the percentage of degrees earned by underrepresented minorities drops off precipitously in fields of NS&E. In contrast, in the social sciences and in non-S&E fields, the drop-off in percentage of degrees earned by underrepresented minorities at advanced levels is not as dramatic. (See figure 4-27 and appendix tables 4-34, 4-35, 4-38, and 4-39.)

Figure 4-27.
S&E degrees earned by underrepresented minority students, by level and field: 1996/97



NOTES: Doctoral-level degrees use 1997 data; all other levels use 1996 data. Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix tables 4-34, 4-35, 4-38, and 4-39.

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Bachelor's Degrees

Bachelor's Degrees, by Sex

The United States is among the leading countries in the world in the proportion of undergraduate S&E degrees earned by women. (See appendix table 4-37.) Trends for women show a smoother, steadier increase in their number of earned degrees in the past several decades than for men, but from a lower base. Male trends in earned S&E degrees show strong growth in the 1950s and 1960s, peaks and valleys in the 1970s and 1980s, and declining or level degrees in all fields except the biological sciences in the 1990s. (See appendix table 4-17.) By 1996, women represented 60 percent of the social and behavioral science degrees, 47 percent of natural sciences, 46 percent of mathematics, 28 percent of computer sciences, and 18 percent of engineering, up considerably from the percentages of 1954. (See text table 4-6.)

Text table 4-6.
Bachelor's degrees earned by women: 1954 and 1996

Field	1954			1996		
		Women			Women	
	Total	Number	Percent	Total	Number	Percent
Total, all fields	292,880	105,380	0.36	1,179,815	651,815	0.55
Science & engineering	117,575	22,743	0.19	384,674	181,333	0.47
Natural sciences	17,710	3,890	0.22	98,322	46,556	0.47
Physical sciences	8,155	1,194	0.15	15,396	5,702	0.37
Biological & agricultural	9,366	2,612	0.28	78,469	39,369	0.50
Earth, atm., & oceanographic	189	84	0.44	4,457	1,485	0.33
Math & computer sciences	4,090	1,368	0.33	37,621	12,764	0.34
Mathematics	4,090	1,368	0.33	13,076	5,992	0.46
Computer sciences	NA	NA	NA	24,545	6,772	0.28
Social & behavioral sciences	73,446	17,420	0.24	185,617	110,697	0.60
Psychology	5,758	2,673	0.46	73,828	53,863	0.73
Social sciences	67,688	14,747	0.22	111,789	56,834	0.51
Engineering	22,329	65	0.00	63,114	11,316	0.18

NA = not applicable

SOURCES: U.S. Department of Health, Education, and Welfare (HEW), *Statistics of Higher Education: Faculty, Students, and Degrees 1953–54* (Washington, DC: U.S. Government Printing Office, 1956), and appendix table 4-17.

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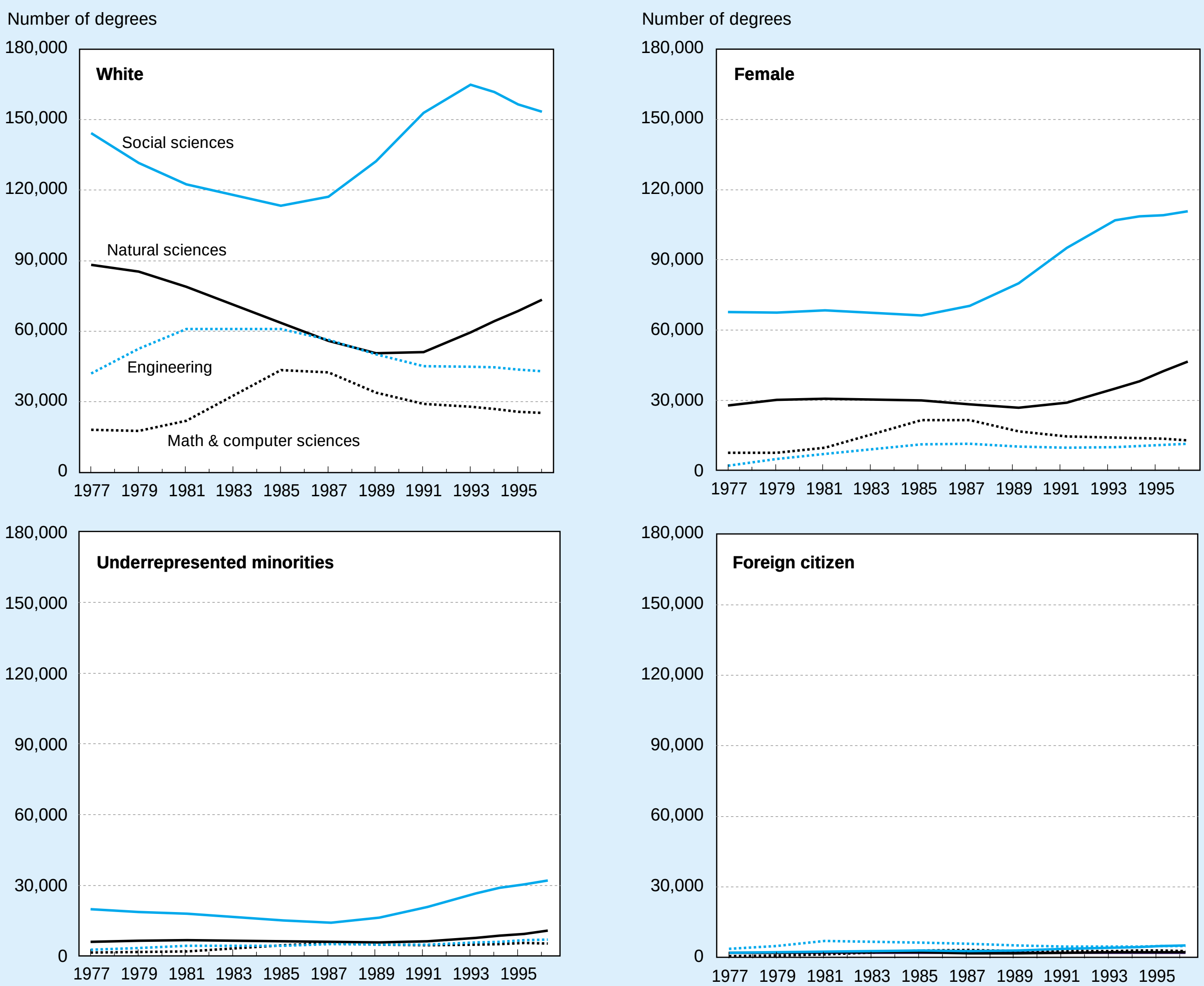
Bachelor's Degrees, by Race/Ethnicity and Citizenship

As discussed in "Trends in Earned S&E Degrees," the number of earned degrees has been increasing in the social and natural sciences and decreasing in engineering, mathematics, and computer sciences. Degrees earned by white and Asian/Pacific Islander students follow this overall pattern.

Trends for subpopulation groups, however, differ somewhat from this overall pattern. The number of degrees earned by the white majority population is declining in every field except the natural sciences. Asian/Pacific Islander students are sharply increasing their earned degrees in the natural and social sciences and leveling off in their number of earned degrees in engineering, mathematics, and computer science fields. Degrees to underrepresented minorities are increasing in all fields, but from a small base. (See figure 4-28.) From 1989 to 1996, degrees earned by underrepresented minority students increased by 10 percent annually in the social sciences, 9 percent in the natural sciences, 6 percent in engineering, and only 1 percent in mathematics and computer sciences.

Foreign students earn few degrees within U.S. universities at the bachelor's level. During the past two decades, S&E degrees earned by foreign students have remained between 3 and 4 percent of total S&E degrees. They are more concentrated, however, in engineering, mathematics, and computer sciences, representing 7 percent of degrees in these fields. Still, trends in these S&E fields are barely visible on a graph. (See figure 4-28.)

Figure 4-28.
Bachelor's degrees in S&E fields earned by selected groups



NOTES: Data for 1983 are estimated. Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix tables 4-17 and 4-35.

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Participation Rates, by Sex and Race/Ethnicity

The United States is among the leading nations in the world in providing broad access to higher education but ranks below many major industrialized countries in the proportion of its college-age population with an S&E background. The ratio of bachelor-level degrees to the college-level population was 32 per hundred in 1996, and the ratio of NS&E degrees to the 24-year-old population in the United States was about 5 per hundred in that same year. (See appendix table 4-18.) These national statistics, however, are not applicable to all minority groups within the United States. The ratio of college degrees earned by black and Hispanic groups to their college-age population was 14 to 18 per hundred, and the ratio of NS&E degrees to this college-age population was 2 per hundred. In contrast, Asians/Pacific Islanders have considerably higher than average achievement: the ratio of bachelor's degrees earned by Asians/Pacific Islanders to their college-age population was 40 per hundred, and their ratio of NS&E degrees to their college-age population was 12 per hundred.

Comparing participation rates in 1980 and 1996 shows some progress toward more diversity in higher education in general and S&E in particular. (See text table 4-7.) While low participation rates for blacks and Hispanics changed little throughout the 1980s, they improved considerably in the 1990s, particularly in the social sciences.

International Comparison of Participation Rates, by Sex

Among countries for which degree data are available by sex, the United Kingdom, Canada, and the United States show relatively high participation rates for both men and women in first university degrees. Among these countries, women in the United Kingdom have the highest participation rate in first university degrees. In 1997, the ratio of first university degrees earned by women to the female 24-year-old population was 38 per hundred, slightly higher than this ratio in the United States and Canada (36 per hundred). Women in the United Kingdom and Canada also show high participation

Text table 4-7.
Ratio of total bachelor's degrees and S&E bachelor's degrees to the 24-year-old population, by sex and race/ethnicity: 1980 and 1996

Sex and race/ethnicity	Total 24-year-old population	Total bachelor's degrees	Degree field: Natural science degrees	Degree field: Social science degrees	Degree field: Engineering degrees	Ratio of Bachelor's degrees to 24-year-old population	Ratio of NS&E degrees to 24-year-old population	Ratio of Social science degrees to 24-year-old population
1980								
Total	4,263,800	946,877	110,468	132,607	63,717	22.2	4.1	3.1
Male	2,072,207	474,336	70,102	64,221	56,654	22.9	6.1	3.1
Female	2,191,593	472,541	40,366	68,386	7,063	21.6	2.2	3.1
White	3,457,800	807,509	100,791	122,519	60,856	23.4	4.7	3.5
Asian/Pacific Islander	64,000	18,908	3,467	2,499	3,066	29.5	10.2	3.9
Black	545,000	60,779	4,932	16,352	2,449	11.2	1.4	3.0
Hispanic	317,200	33,167	3,646	5,748	1,820	10.5	1.7	1.8
American Indian/ Alaskan Native	29,800	3,593	337	682	195	12.1	1.8	2.3
1996								
Total	3,671,000	1,179,815	135,943	185,617	63,114	32.1	5.4	5.1
Male	1,864,000	528,488	76,623	74,920	51,798	28.4	6.9	4.0
Female	1,806,000	651,815	59,320	110,697	11,316	36.1	3.9	6.1
White	2,472,000	884,128	98,707	153,277	43,098	35.8	5.7	6.2
Asian/Pacific Islander	161,000	63,117	13,212	11,020	6,799	39.2	12.4	6.8
Black	505,000	89,554	8,670	17,385	3,000	17.7	2.3	3.4
Hispanic	500,000	71,015	6,764	13,296	3,731	14.2	2.1	2.7
American Indian/ Alaskan Native	33,000	6,813	741	1,324	243	20.6	3.0	4.0

NOTES: The ratios are the number of degrees to the 24-year-old population on a scale of 1 to 100. Population data are for U.S. residents only and exclude members of the armed forces living abroad.

SOURCES: Population data—U.S. Bureau of the Census, *U.S. Population Estimates by Age, Sex, Race, and Hispanic Origin: 1990 to 1997,* PPL-91R (Washington, DC), and previous editions; Degree data—National Center for Education Statistics (NCES), Earned Degrees and Completion Surveys (Washington, DC: 1997), unpublished tabulations, and National Science Foundation, Science Resources Studies Division, *Science and Engineering Degrees 1966–96*, NSF 99-330, Author, Susan T. Hill (Arlington, VA: 1999).

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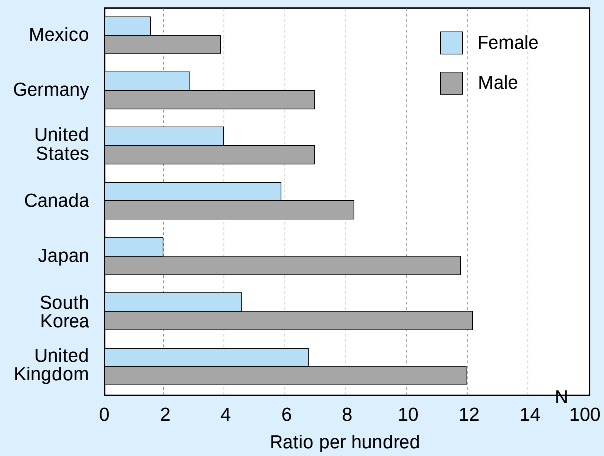
rates in NS&E degrees at the bachelor's level. In 1997, the ratio of NS&E degrees earned by women within the United Kingdom to the female 24-year-old population was 6.7 per hundred, about one-half the U.K. male participation rate. The participation rates for men and women in Canada are more similar. (See figure 4-29 and appendix tables 4-36.)

Among Asian countries, women earn first university degrees at a rate similar to or higher than many European countries. However, only in South Korea do women have high participation rates in NS&E degrees. In 1997, the ratio of their earned degrees in these fields to the female 24-year-old population was 4.5 per hundred, higher than the participation rate of women in other Asian countries, Germany, or the United States. (See figure 4-29.) Among all reporting countries, women earn the highest proportion of S&E degrees in the natural and social sciences. (See appendix table 4-37.)

Figure 4-29.
Ratio of NS&E degrees to the college-age population, by country and sex



See appendix table 4-36. *Science & Engineering Indicators – 2000*

Graduate Enrollment, by Citizenship, Race/Ethnicity, and Sex

Is the United States educating adequate numbers of bachelor-level S&E majors who are willing and able to pursue advanced degrees in S&E? This issue, voiced by Steelman in 1947, is still of interest to scientific and professional societies and to graduate programs of U.S. universities. The concern has been broadened, however, to ensuring access to women and underrepresented minorities in graduate S&E programs. The following section presents trends in graduate enrollment: strong growth of foreign students and the more modest growth in graduate enrollment of U.S. citizens for the period 1983–93, followed by declining graduate S&E enrollment for both U.S. and foreign citizens. It also provides data on increasing gender equity in graduate S&E fields.

For the period 1983–92, growth in enrollment in U.S. graduate programs in S&E depended on the entry of foreign students, particularly in programs of NS&E. During this period, foreign graduate student enrollment increased at an average annual rate of 5 percent. At the peak of their enrollment in U.S. graduate programs, 1992, foreign students represented one-fourth of all S&E students and an even larger percentage in some fields—one-third of the students in engineering, mathematics, and computer sciences. (See appendix table 4-22.) Recently, increased capacity for graduate S&E education within Asian countries and other career options for Asian students have contributed to the decreasing enrollment of foreign students in U.S. institutions. From 1993 to 1996, foreign graduate student enrollment declined at an average annual rate of 3 percent, with a slight upturn in 1997. Foreign student enrollment should be monitored to see whether the slight increase in enrollment in 1997 is a one-year fluctuation or a reversal of a trend toward fewer foreign graduate students in U.S. higher education.

In contrast, U.S. citizens, including the majority white population and Asians/Pacific Islanders, increased their enrollment in graduate S&E programs at a modest rate of 1 percent for the period 1983–93 and decreased their enrollment 3 percent annually since then. Underrepresented minorities, however, showed continual steady progress in increasing graduate enrollment. For the period 1983–95, underrepresented minority students increased their enrollment in graduate programs in fields of NS&E at an average annual rate of 6 percent, but from a low base. In the past two years, this growth rate slowed to less than 3 percent. By 1997, underrepresented minorities were 9 percent of graduate enrollment in S&E fields. (See appendix table 4-22.)

The long-term trend of women's increasing proportion of enrollment in all graduate S&E fields has continued during the past two decades. By 1997, women were 38 percent of graduate enrollment in the natural sciences, 19 percent in engineering, and 58 percent in fields of social and behavioral sciences. However, males are not as prevalent in fields of NS&E among underrepresented minority groups; women in these groups have a higher proportion of graduate enrollment compared with the overall average. For example, women are one-third of black graduate students in engineering and more than one-half of the black graduate students in fields of natural sciences. (See text table 4-8.)

Master's Degrees

Master's Degrees, by Sex

Gender equity in S&E degrees at the master's level has improved continually during the past four decades. Such degrees earned by women increased from 1,744 in 1954 to more than 37,000 in 1996, representing 39 percent of all S&E degrees at the master's level in 1996. By far the largest growth has been in the social sciences. Gender equity has been reached in the biological sciences. Modest increases have occurred in engineering, physical sciences, mathematics, and computer sciences.

Text table 4-8.
Percentage of female enrollment in graduate S&E programs among racial and ethnic groups and foreign students: 1997

Status/race and ethnicity	Natural sciences	Social sciences	Engineering
Total	38	58	19
White	38	59	18
Asian/Pacific Islander	42	61	22
Black	53	66	32
Hispanic	44	61	23
American Indian/ Alaskan Native	44	61	24
Foreign students	33	42	17

NOTE: Natural sciences include physical, biological, agricultural, earth, atmospheric, and oceanographic sciences, mathematics, and computer sciences. Social sciences include psychology, sociology, and other social sciences.

SOURCE: National Science Foundation, Science Resources Studies Division, *Graduate Students and Postdoctorates in Science and Engineering: Fall 1997*, NSF 99-325, Project Officer, Joan Burrelli (Arlington, VA: 1999).

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By 1996, women earned 58 percent of the master's degrees in the social and behavioral sciences and 49 percent in the biological sciences. However, they earned only 27 percent of computer science degrees and 17 percent of those in engineering. Degrees to males have declined in engineering for the past two years, mainly accounted for by declining engineering enrollment of foreign students. (See appendix table 4-23.)

Master's Degrees, by Race/Ethnicity

Minority groups continued to increase their proportion of S&E degrees earned at the master's level. Asians/Pacific Islanders have been increasing the number of master's degrees earned in all fields of S&E for two decades, except for the recent leveling off in engineering fields. (See appendix table 4-38.) The number of master's degrees earned by underrepresented minority graduate students increased modestly in all fields of S&E (especially in the social sciences) from 1990 to the present. (See figure 4-30.) In 1996, underrepresented minorities earned 7.4 percent of the S&E degrees at the master's level. (See appendix table 4-38.)

Master's Degrees, by Citizenship

The number of master's degrees earned by U.S. citizens and permanent residents declined or leveled off in engineering, mathematics, and computer science degrees. (See appendix table 4-38.) The number of master's degrees increased only in the natural sciences, particularly in the agricultural and biological sciences. U.S. citizens earned increasing numbers of master's degrees in the biological sciences. Along with engineering, agriculture is a popular major for foreign students in U.S. as well as Japanese universities. Until 1991, foreign students on temporary visas earned 25 percent of the master's degrees in agricultural science. Chinese foreign students, who shifted to permanent resident status with the 1992 Chinese Student Protection Act, may account for the sharp jump in agricultural degrees recorded between 1992 and 1996 for U.S. citizens and permanent residents (NSF 1999b).

Master's degrees earned by foreign students (on temporary visas), which had increased for two decades, slightly declined in fields of S&E in 1996. Fewer foreign graduate students enrolling in engineering since 1994 account for the fall-off in master's degrees in engineering. (See appendix table 4-38.)

Doctoral Degrees

Doctoral Degrees, by Sex

Women have made continual progress toward gender equity in S&E degrees earned at the doctoral level. The proportion of doctoral S&E degrees earned by women increased from 6 percent in 1954 to 33 percent in 1997. The largest gains were made in the social sciences, from approximately 9 percent in 1954 to 51 percent in 1997, and in the natural sciences, from 5 percent in 1954 to one-third in 1997. In engineering, however, doctoral degrees earned by women increased from 0 percent in 1954 to 12 percent in 1997. (See figure 4-31.)

Among countries with disaggregated data on doctoral degrees by sex, women in France have the highest representation in S&E fields. More than 41 percent of the doctoral degrees in the natural sciences are earned by women and almost 23 percent of the engineering degrees. In comparison, women in the United States earn about 34 percent of the S&E degrees at the doctoral level, almost 35 percent of the natural science degrees, and 12 percent of the engineering degrees. (See text table 4-9 and appendix table 4-40.)

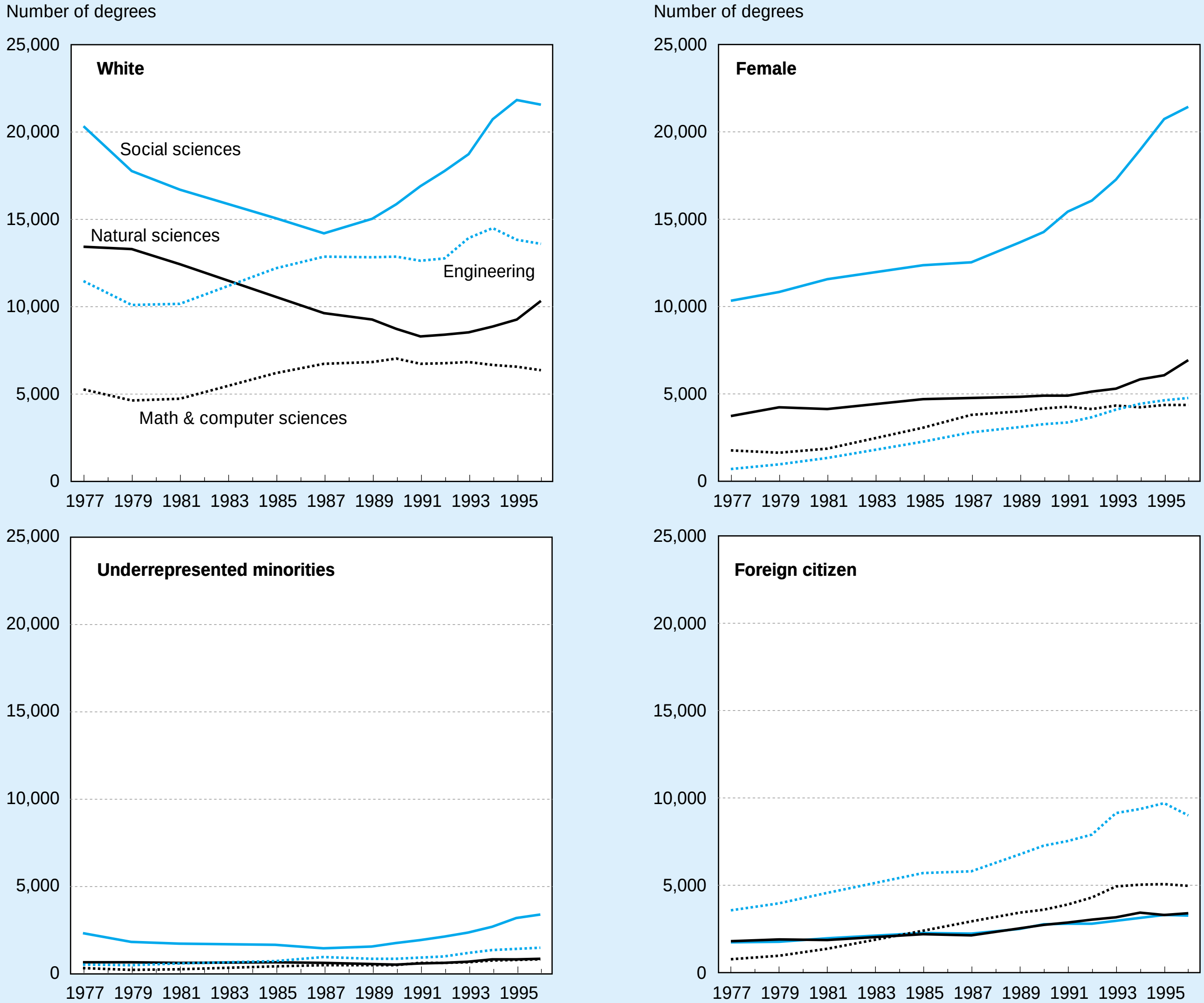
Doctoral Degrees, by Race/Ethnicity

In the period 1977–97, the majority white population earned a stable number of degrees in all fields of science, but an increasing number in engineering fields from 1985 until 1995. After 1995, engineering doctoral degrees earned by whites also leveled off. Underrepresented minorities made steady progress in earned doctoral degrees in NS&E from 1985 to 1997, but maintained a low and level number of degrees in the mathematics and computer science fields. Their doctoral degrees are barely visible on a graph that uses the same scale to compare S&E degrees earned by various groups. (See figure 4-32.) In the 1990s, very steep increases in doctoral degrees in all S&E fields among Asians/Pacific Islanders who were citizens and permanent residents mainly reflect the Chinese foreign students on temporary visas shifting to permanent resident status from the 1992 Chinese Student Protection Act.

Doctoral Degrees, by Citizenship

Each year from 1986 to 1996, an ever-larger number of foreign students earned S&E doctoral degrees from U.S. universities. The number of such degrees earned by foreign stu-

Figure 4-30.
Master's degrees in S&E fields earned by selected groups



NOTES: Data are estimated for 1983. Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix tables 4-23 and 4-38.

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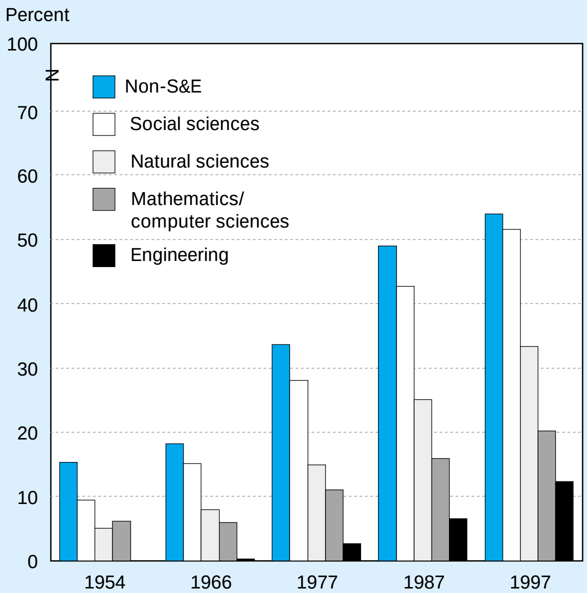
dents increased far faster (7.8 percent annually) than those earned by U.S. citizens (2 percent annually). (See appendix table 4-26.) This decade-long trend of increasing number of S&E doctoral degrees earned by foreign students halted in 1997. In that year, the number of degrees earned by foreign doctoral students dropped by 15 percent (see figure 4-33); their enrollment in U.S. graduate S&E programs had declined from 1993 to 1996 and slightly increased in 1997. Students in several Asian countries are becoming somewhat less dependent on U.S. universities for advanced training, particularly in NS&E. (See "International Comparison of Doctoral Degrees in S&E.")

Foreign students earn a larger proportion of degrees at the doctoral level than in any other degree level. (See figure 4-34.) This concentration increased for a decade, from the mid-1980s to the mid-1990s, peaked in 1996 at 40 percent of all S&E doctoral degrees, and declined in 1997 to 34 percent.

International Comparison of Foreign Doctoral Recipients. Like the United States, the United Kingdom, Japan, and France have a large percentage of foreign students in their doctoral S&E programs. In 1997, foreign students earned 45 percent of the doctoral engineering degrees awarded within U.K. universities, 43 percent within Japanese universities, and 49 percent within U.S. universities. In that same year, foreign students earned more than 21 percent of the doctoral degrees in the natural sciences in France, 29 percent in the United

Figure 4-31.
Proportion of doctoral degrees earned by women in U.S. universities, by field



NOTES: Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

SOURCES: U.S. Department of Health, Education, and Welfare, *Statistics of Higher Education: Faculty, Students, and Degrees 1953–54* (Washington, DC: U.S. Government Printing Office); National Science Foundation, Science Resources Studies Division, *Science and Engineering Degrees, 1966–96.* NSF 99-330, Author, Susan T. Hill (Arlington, VA); and appendix table 4-25.

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Kingdom, and 36 percent in the United States. (See text table 4-10.)

Stay Rates of Foreign Doctoral Recipients. Historically, about one-half the foreign students who earned S&E doctoral degrees within U.S. universities planned to locate in the United States, and a smaller proportion, about 40 percent, had firm offers to do so. In the 1990s, however, foreign doctoral recipients from Asia, Europe, and North America increasingly planned to stay in the United States and received firm offers to do so. By 1997, 69 percent of foreign doctoral recipients in S&E fields planned to stay in the United States following the completion of their degrees, and 50 percent had accepted firm offers to do so. (See appendix tables 4-42 and 4-43.)

In a recent study of foreign S&E doctoral recipients from 1988 to 1996, 39 percent reported they had firm work or study offers in the United States at the time the survey was conducted. Of the 39 percent who received firm offers to stay, 22 percent were for postdoctoral positions, and 17 percent were for employment offers. The primary work activity identified in these offers from industry was R&D. Industry was more likely to make offers to new foreign Ph.D.s who majored in engineering, the physical sciences, and computer science than to those who majored in other fields (NSF 1998).

The decision of foreign doctoral recipients in S&E fields to remain in the United States has implications for the U.S. economy and the concentration of scientists and engineers in the United States, as well as for the economies of the nations from which these students come. For example, in the 1990s, the number of South Korean and Taiwanese S&E doctoral recipients reporting plans to remain in the United States declined because the economies of South Korea and Taiwan increased those countries' capacities to absorb the majority of

Text table 4-9.
Percentage of doctoral S&E degrees earned by women, by country: 1997 or most current year

Region/country	All S&E degrees	Degree field: Natural sciences	Math/ computer sciences	Agricultural sciences	Social sciences	Engineering
Asia						
Japan	10.4	10.2	7.7	15.7	23.4	5.5
South Korea	10.5	18.8	31.0	14.0	13.4	3.0
Taiwan	10.8	15.2	14.3	38.5	25.8	2.3
Europe						
France	35.0	41.4	22.9	51.2	36.3	22.5
Germany	22.5	25.9	17.1	35.5	27.5	8.3
United Kingdom	27.7	34.4	18.4	31.6	32.7	13.4
North America						
Canada	26.7	22.4	14.2	36.9	50.2	9.1
Mexico	33.8	32.7	18.2	27.1	43.3	18.5
United States	33.7	34.9	20.2	26.4	51.6	12.3

See appendix table 4-40.

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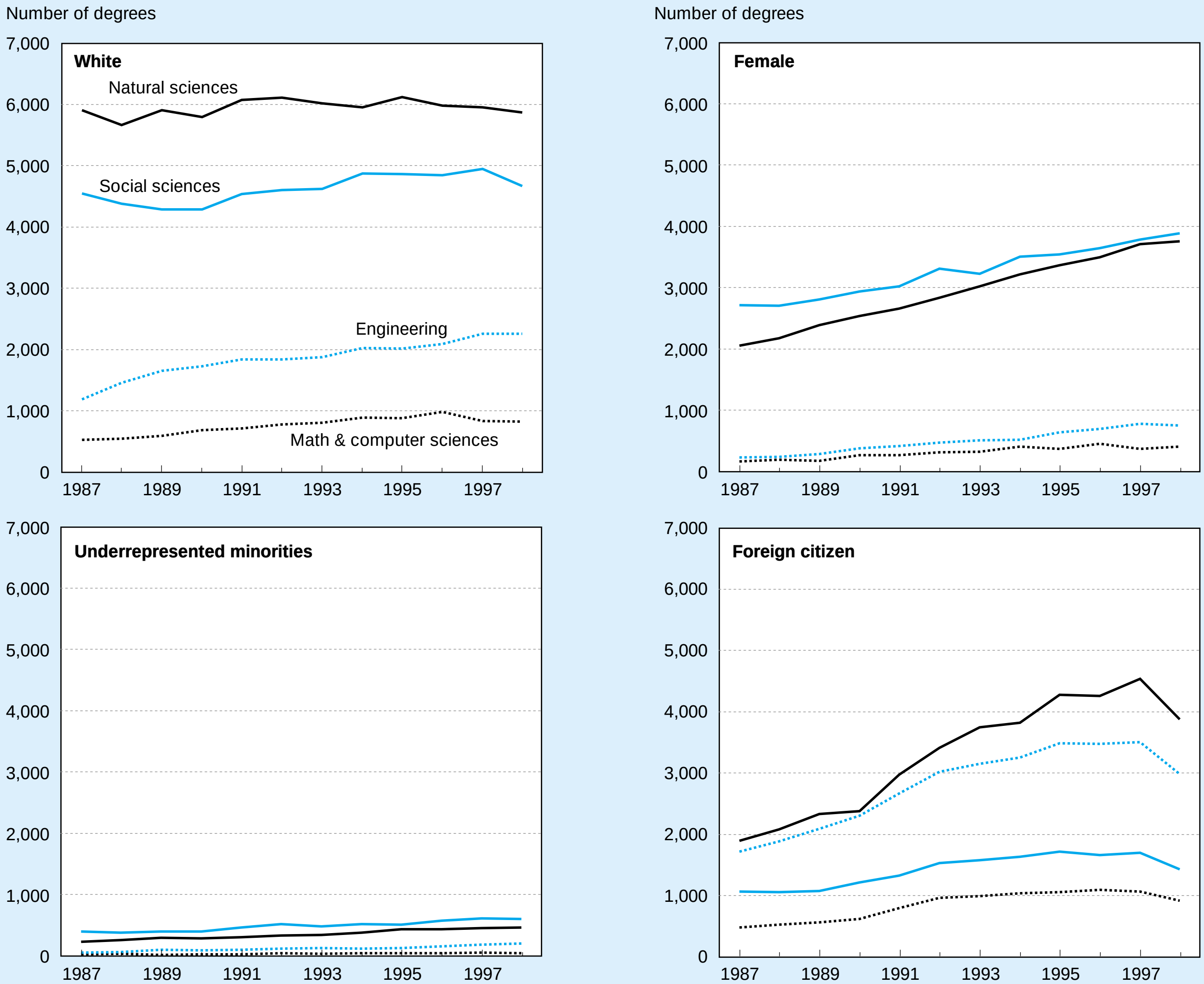
Figure 4-32.
Doctoral degrees in S&E fields earned by selected groups



NOTES: Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

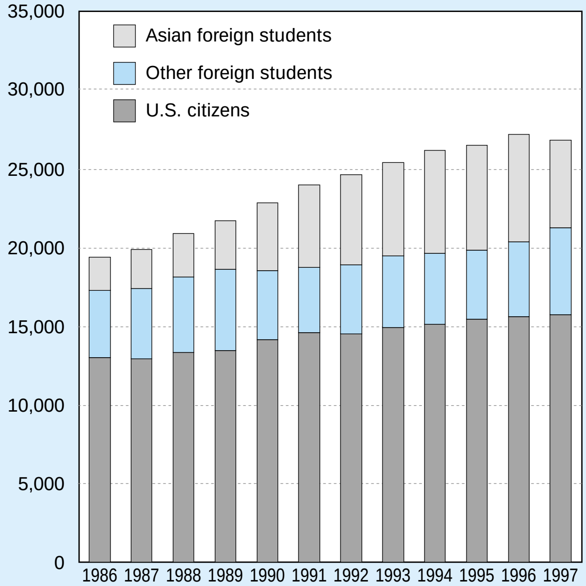
See appendix tables 4-25, 4-26, and 4-39. *Science & Engineering Indicators – 2000*

the U.S.-trained doctoral scientists and engineers. In 1997, however, a larger percentage of foreign students from all Asian countries sought to remain in the United States, possibly reflecting the Asian economic crisis. However, since the S&E doctoral degrees earned by foreign students dropped 15 percent in 1997 (see appendix table 4-26), the numbers actually staying also decreased by 8 percent in that year. (See appendix table 4-42; for the decrease in doctoral recipients from the major countries of origin in North America, Europe, and Asia and the decreasing numbers planning to stay, see figure 4-35 and appendix table 4-43.)

A recent study of foreign doctoral recipients working and earning wages in the United States (Finn 1999) shows that about 53 percent of the foreign students who earned S&E doctorates in 1992 and 1993 were working in the United States in 1997. The stay rates are higher in physical and life sciences and in engineering and lower in the social sciences. For example, 61 percent of the foreign students who earned a doctorate in computer sciences in 1992 and 1993 were employed in the United States four to five years later, while only 32 percent of those in the social sciences were employed in the United States. (See chapter 3.)

Stay rates differ more by country of origin than by discipline, however. The large majority of 1992 and 1993 engineering doc-

Figure 4-33.
U.S. doctoral S&E degrees earned by U.S. and foreign citizens: 1986–97



See appendix table 4-41 for Asian countries included.

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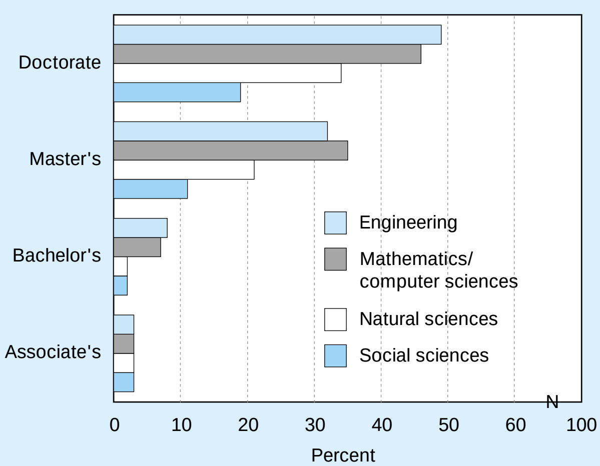
Figure 4-34.
S&E degrees earned by foreign students, by level and field



NOTES: Associate's, bachelor's, and master's degree data are for 1996; doctoral degree data are for 1997. Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

See appendix tables 4-34, 4-35, 4-38, and 4-39.

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Text table 4-10.
Percentage of NS&E doctoral degrees earned by foreign students in selected countries: 1997

Country	Natural sciences[1]	Engineering
United States	36.2	49.4
France	21.1	31.5
Germany	6.9	12.0
Japan[2]	25.8	42.6
United Kingdom	28.9	44.7

[1]Natural sciences include mathematics, computer sciences, and agricultural sciences.
[2] Percentage of NS&E doctoral degrees earned by foreign students within Japanese universities only; not those earned within industry.

SOURCES: **France**—Ministère de l'Éducation National, de la Recherche, et de la Technologie, *Rapport sur les Études Doctorales* (Paris: 1998); **Germany**—Statistisches Bundesamt, *Prüfungen an Hochschulen* (Wiesbaden: 1998); **Japan**—Ministry of Education, Science, and Culture (Monbusho), *Monbusho Survey of Education* (Tokyo: annual series); **United Kingdom**—Higher Education Statistical Agency, *Students in Higher Education Institutions, 97/98* (Cheltenham: 1999); **United States**—National Science Foundation, Science Resources Studies Division, *Science and Engineering Doctorate Awards: 1997,* NSF 99-323 (Arlington, VA: 1999).

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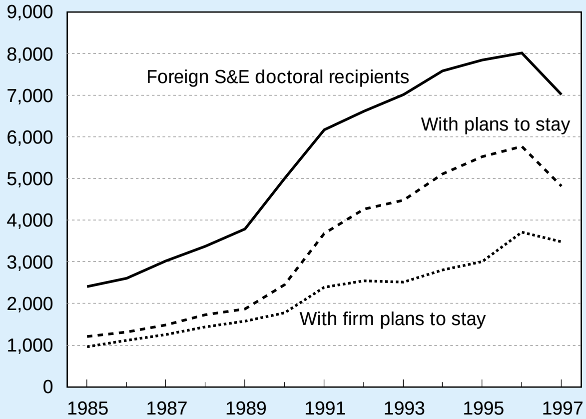
toral recipients from India (90 percent) and China (97 percent) were working in the United States in 1997. In contrast, only 8 percent of South Koreans who completed engineering doctorates from U.S. universities in 1992 and 1993 were working in the United States in 1997. (See appendix table 4-44.)

Stay rates for foreign students are not static. Because China is now the main country of origin of foreign S&E doctoral recipients in the United States, the trend toward increasing stay rates in the 1990s should be followed to see whether it is temporary. Should China succeed in implementing economic reforms that rely heavily on scientific and technological progress, the demand for high-level specialized personnel and the number of new Ph.D.s returning to China may increase substantially.

Postdoctoral Appointments

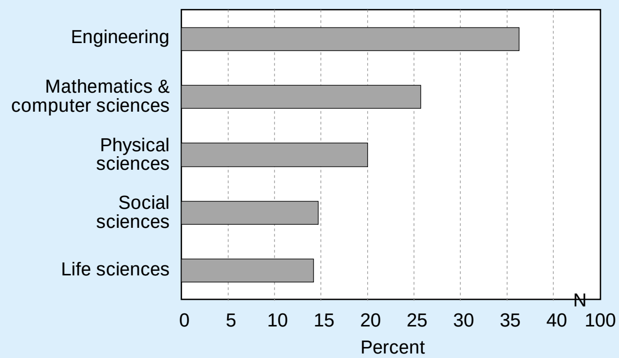
Postdoctoral researchers play an important role in the dissemination of S&E knowledge and new techniques, and Japan and European countries are introducing more postdoctoral researchers as a way to improve the vitality of their science (AAAS 1999 and Frijdal and Bartelse 1999.) By 1997, postdoctoral researchers in the United States numbered more than 38,000. Postdoctoral appointments for research are made primarily in fields of science and medicine, rather than in engineering. In 1997, postdoctorates in engineering made up only 8 percent of the 38,000 postdoctorates in all surveyed fields. In that year, foreign researchers performed a slight majority (53 percent) of S&E postdoctoral research. These percentages differ, however, in fields of science versus engineering. Postdoctoral appoint-

Figure 4-35.
Foreign S&E doctoral recipients (from North America, Europe, and Asia) with plans to stay in the United States: 1985–97



See appendix table 4-43 for countries included in each region.
Science & Engineering Indicators – 2000

Figure 4-36.
Foreign-born S&E faculty in U.S. higher education, by field: 1997



See appendix table 4-46. *Science & Engineering Indicators – 2000*

ments in fields of science are filled by approximately equal numbers of U.S. and foreign researchers; engineering postdoctorates are filled more often by foreign researchers (63 percent). (See appendix table 4-45 and chapter 3 for further discussion of postdoctoral appointments.)

International Dimension of U.S. Higher Education Faculty

One indicator of mobility of S&E personnel in the world is the proportion of foreign-born faculty in U.S. higher education. The United States has been a magnet for trained scientists and engineers because of a well-developed economy able to absorb high-level personnel. (See chapter 3 for the proportion of immigrant scientists and engineers in the overall U.S. labor force.)

The U.S. university system has been able to employ considerable numbers of foreign-born scientists and engineers.[20] In 1997, of the 225,000 faculty teaching S&E in four-year institutions, 45,000 are foreign-born scientists and engineers. Foreign-born faculty in U.S. higher education represent more than 36 percent of the engineering professors and more than one-quarter of the mathematics and computer science teachers. (See figure 4-36.) These faculty are mainly from Asian and European countries, with the largest numbers coming from India, China, and England. (See text table 4-11.) The vast majority of these faculty earned their doctoral education in U.S. universities. However, those who received their doctoral education outside the United States and began teaching in U.S. universities after 1993 are not captured in the NSF's SESTAT database. Therefore, the percentages of foreign-born faculty are underestimations, particularly from the countries of the former Soviet Union. Faculty from these countries are most likely to have obtained their doctoral degrees before immigrating to the United States and may have come after 1993. (See appendix tables 4-46, 4-47, and 4-48.)

Text table 4-11.
Major countries of origin of foreign-born S&E faculty members in U.S. universities: 1997

Place of origin	Number	Percentage
Total S&E faculty	224,707	100.0
U.S.-born	179,698	80.0
Foreign-born	45,009	20.0
Total S&E faculty from major countries of origin	21,545	9.6
India	6,876	3.1
China	4,830	2.1
United Kingdom	3,426	1.5
Taiwan	1,820	0.8
Germany	1,309	0.6
South Korea	1,218	0.5
Greece	1,044	0.5
Japan	1,022	0.5
Other	23,464	10.4

NOTE: Data include scientists and engineers whose first job is in S&E postsecondary teaching at four-year colleges and universities in the United States; it excludes scientists and engineers who may teach as a secondary job.

See appendix table 4-48. *Science & Engineering Indicators – 2000*

[20]These data are based on the integrated data files of the NSF SESTAT system, a system of data about the S&E workforce.

Conclusion

The capacity to provide higher education in S&E is expanding throughout the world, with multiple poles of concentration in Europe, Asia, and the Americas. The expansion of S&E higher education in these and other regions, and the consequent decline in the U.S. proportion of S&E degrees, is likely to continue. This increasing global capacity in S&E education, with recent growth in graduate education capacity, has implications for the United States as well as for all nations. Higher participation rates in S&E degrees and a greater focus on S&E fields in higher education in other countries contribute to their potential pool of scientists and engineers. Such human capital is important for addressing complex societal needs and for technological innovations.

These world regions are attempting to create important additional factors for innovation besides S&E degrees and recognize a lag time between S&E degree production and other needed S&E infrastructure that would contribute to their economic competitiveness. Creating graduate S&E departments has proven easier than creating jobs to employ the recent graduates, particularly in developing countries. Nonetheless, a larger global capacity for S&E education implies U.S. needs for (1) S&T information on other world regions and (2) consideration of heightened levels of international scientific cooperation in emerging regions. In addition, the global expansion of S&E knowledge has potential benefits of quickening the pace of development in other world regions.

This global diffusion parallels some limited domestic progress; U.S. higher education in S&E is becoming more diverse, particularly at the undergraduate level. In the 1990s, white enrollment in undergraduate education leveled off and began to decline, while enrollment for all minority groups increased. Similarly, while overall undergraduate engineering enrollment has been declining, enrollment of women and minorities has been increasing, particularly in the 1990s. At the bachelor's level, the number of degrees earned by underrepresented minorities is increasing slightly in NS&E fields and very rapidly in the social sciences. Compared with a decade ago, recent participation rates, disaggregated by race/ethnicity and sex, show considerable progress toward increasing diversity by sex in S&E fields and more limited progress in increasing diversity by race/ethnicity.

The constancy of the ratio of NS&E degrees to the college-age population (5 per hundred) and the declining college-age population have accounted for the decade-long decline in NS&E degrees. This relatively low U.S. participation rate in NS&E degrees compared with other countries may be inadequate for the current and future economy, as reflected in the high number of foreign-born skilled workers who have been provided special visas to attempt to meet the needs of U.S. high-technology industries and services. In addition, the lower participation rates of underrepresented minority groups, currently 28 percent of the U.S. college-age population (see "Diversity Patterns in S&E Enrollment and Degrees in the United States") should be monitored as these groups increase their proportion of the U.S. workforce.

At the graduate level, there have been considerable progress for women and limited progress for minorities in S&E programs. At the master's level, women have made significant progress in earned degrees in the natural sciences, but underrepresented minority groups showed only modest growth in these fields. At the doctoral level, the share of S&E degrees earned by women has more than doubled, from 15 percent in 1975 to 33 percent in 1997. Underrepresented minority students have slightly increased their proportion of doctoral S&E degrees to 7 percent in 1997, from 5 percent in 1987.

The large capacity of U.S. graduate S&E programs in the late 1980s was increasingly met through foreign students, but S&E graduate programs have recently seen a slightly lower concentration of foreign students. The rate of growth in S&E master's degrees earned by foreign students slowed in the 1990s. The declining graduate enrollment of foreign students in engineering since 1993 has resulted in the 1996 fall-off of the number of master's degrees in engineering earned by foreign students. At the doctoral level, the proportion of NS&E degrees earned by foreign citizens reached 47 percent in 1994, but declined to 40 percent by 1997.

Despite these declines, graduate education in the United States will continue to have a large proportion of foreign students in S&E fields, as do France and the United Kingdom. As countries attempt graduate education reforms to improve the quality of their research universities, they will continue to send their students to U.S. research universities and encourage them to remain for postdoctoral training and an industrial research experience. This combination of doctoral education and research experience provides valuable skills to the home country, even in an advisory capacity if the young scientists and engineers remain in the United States for employment.

The U.S. university system has accelerated the diffusion of S&E knowledge in the world through teaching foreign doctoral students who have contributed to the S&T infrastructure in the United States and in their home countries. Besides the global good of enhancement of scientific knowledge and world development, U.S. higher education is itself enriched by the network of former doctoral students and faculty in key research centers in Asia and Europe. The benefits include enhanced cooperative research opportunities, expanded opportunities for U.S. graduate and undergraduate students to study abroad, and international postdoctoral research positions for young U.S. scientists and engineers.

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